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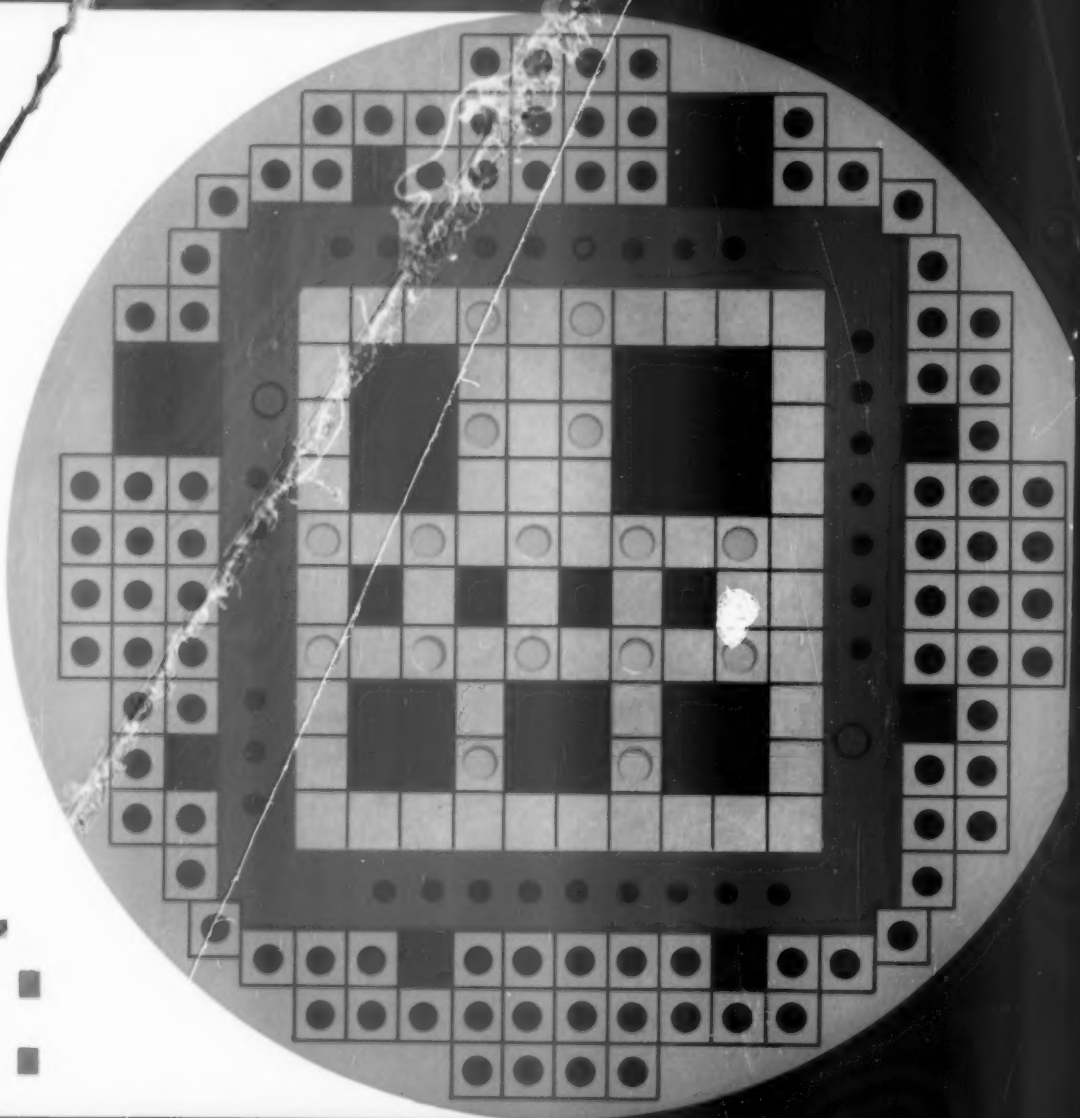

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page 41

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About NUCLEONICS

Front cover. Although it's probable that the uninitiated don't realize it, a great deal of blood, sweat, tears, intuition and prayers go into the creation of a NUCLEONICS front cover. This month's creation on the Engineering Test Reactor (see p. 41) is no exception.

The original idea we had on how to display the drama of ETR on the cover was to use a photograph of the two buildings housing ETR and MTR, sitting next to one another amid the vastness of the Idaho desert—the world's greatest concentration of neutrons being used exclusively for irradiation testing. But, although the photo could be taken for us, we were advised that it would be tough to get the military to clear it in time to meet our schedule—tough because such a shot would apparently be useful as military target information.

And so we fell back on a more abstract idea, the one that actually wound up on the cover. We were intrigued about using this diagram of the core of ETR because we felt that this particular month we could do it justice because, for the first time, we were using three colors on the cover instead of our normal two and could thus get the effect we were seeking.

●

Clippability. On at least several occasions in recent years, subscribers have exercised a prerogative we love to see them exercise, namely, to write us irate letters on a pet peeve of theirs. We've just gotten a friendly, constructively critical epistle from a gentleman from Oak Ridge. He tells us to "quit concluding one article on the front side of a page and starting another on the reverse side . . . This practice makes it rough on the person who clips and files a good number of articles out of your magazine."

Of course, we're tickled at this degree of interest in NUCLEONICS. But the problem isn't easy to solve. For greater effectiveness in presentation of information and to increase ease of reading, we try as much as possible to start each article on a lefthand page so that our art director will have two-page "spreads" to work with for his layouts rather than single pages, which are so restrictive. We're quite convinced that this pays off for the reader.

However, there is a very easy answer for our Oak Ridge correspondent. Virtually every one of our articles is reprinted at the request of the authors. So we suggest this to those interested in saving articles published in NUCLEONICS: do exactly as many of our readers already do—get a batch of postcards made up that read, "Dear Sir, Kindly send me a reprint of your article, ' . . . ,' that appeared in the . . . issue of . . . " Then, it becomes a simple matter to file articles you want to save.

●

Nuclear mnemonics. We're always casting around for new features to add to NUCLEONICS. One idea we recently had was for a department called "Nuclear Mnemonics" (a mnemonic, remember, is a device intended to help you remember some fact).

Now we never did get Nuclear Mnemonics off the ground but we do want to share with you at this time what would have been its first item. It's a mnemonic based on the word mnemonic itself and is intended to provide a key for the Poisson formula for the distribution of counts in radioactive decay. The formula is

$$\frac{m^n e^{-m}}{n!}$$

and this can be gotten out of the word mnemonic by reading it letter by letter as m to the n, e to the minus m, over n factorial (the *ic* is supposed to stand for the factorial and it certainly does seem onomatopoetic on the exclamation point).

We are indebted to Prof. Larry Spruch of the Physics Department of New York University for that particular gem—maybe if enough readers send in memory devices, short cuts for remembering conversion factors or the number of submarines in the naval reactor program or what have you, we'll be forced to get Nuclear Mnemonics going on a regular basis. Send any entries to Mnemonics Editor, NUCLEONICS, 330 West 42nd St., New York 36, New York.

●

Coming events. In Vol. 1, No. 1 of NUCLEONICS, the inside back cover was devoted to a feature called, "Future Issues Will Feature." For some inexplicable reason we later dropped it.

This month—below—we reinstitute these previews. In the not-very-monumental process of preparing the listing below, we looked back at the preview listing in our first issue to see where NUCLEONICS has come in 10 years. We thought you too might be interested in this comparison. These are the seven articles we listed then: Nuclear Induction Methods for Isotope Analysis, Tracer Isotopes in Metallurgy, Survey of Particle Accelerator Design, Nuclear Fundamentals of Nuclear Reactors, Meson Theory, Research with C^{14} and Radioactivity Units and Standards.

Coming Features in NUCLEONICS

April - Where Does Fast Reactor Technology Stand Today?

May - Special Report, "Simulation and Computation in Nuclear Engineering"

- Nondestructive Testing in Nuclear Energy

June - Special Issue on Experimental Boiling Water Reactor

NUCLEONICS (with which is consolidated "Atomic Power" and "Atomic Engineering") March, 1957, Vol. 15, No. 3. Published monthly by the McGraw-Hill Publishing Co., Inc., Executive, Editorial, Advertising and Subscription Offices: McGraw-Hill Building, 330 West 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. Entered as second class matter December 17, 1947 in the Post Office at York, Pa., under the act of March 3, 1879. Copyright 1957 by McGraw-Hill Publishing Company, Inc. All rights reserved. Donald C. McGraw, President; Joseph A. Gerardi, Executive Vice President and Treasurer; John J. Cooke, Secretary; Nelson Bond, Executive Vice President, Publications Division; Ralph B. Smith, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator. FOR SUBSCRIPTIONS, write to Nucleonics-Subscription Service, 330 West 42nd Street, New York, 36, N. Y. Orders must indicate company and position. Allow one month for change of address. Price per copy $.75. Subscription rates: United States and U. S. Possessions $8 for 1 year, $12 for 2 years, $16 for 3 years. Canada $10 for 1 year, $16 for 2 years, $20 for 3 years. Other Western Hemisphere countries and the Philippines $10 for 1 year, $16 for 2 years, $20 for 3 years. All other countries $15 for 1 year, $25 for 2 years, $30 for 3 years. Member of ABC. Member of ABP.

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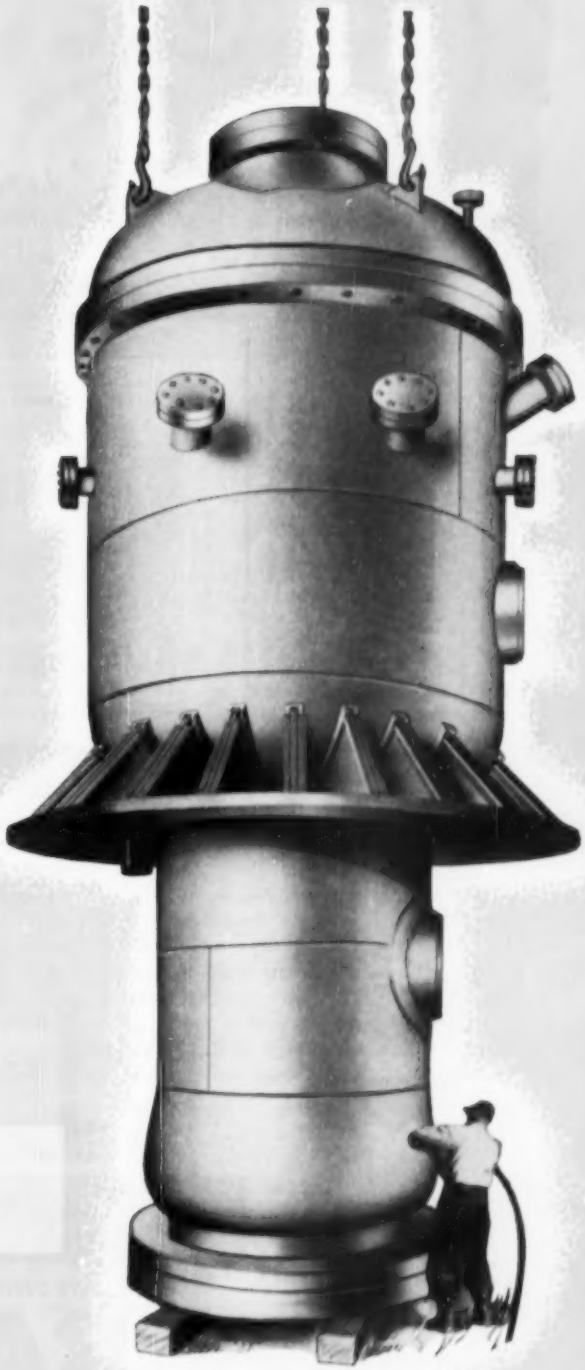

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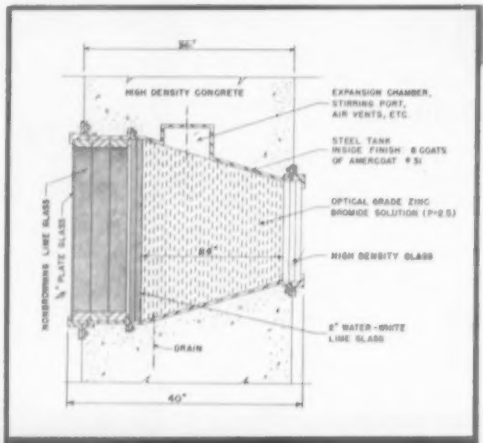
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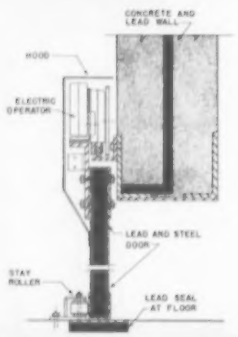
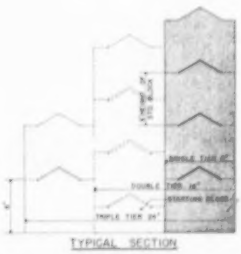


SHIELDED & MOTORIZED RADIATION DOORS



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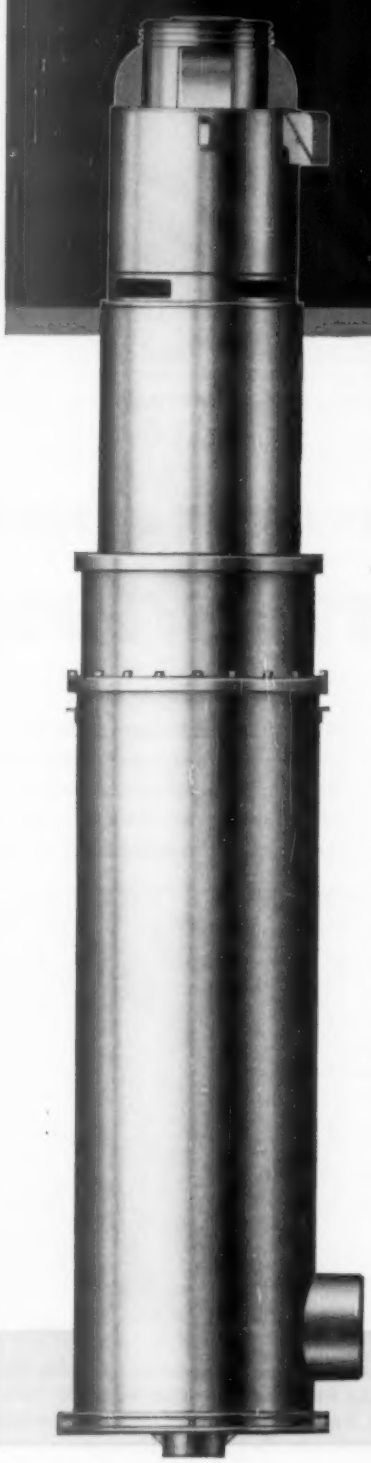

BJ Liquid Sodium Pump

WORLD'S LARGEST LIQUID SODIUM PUMP FEATURES MANY DESIGN "FIRSTS"

This new Byron Jackson pump will be used as a primary cooling pump for one of the nation's first full-scale commercial power plants using nuclear fuel.

The pump is approximately 32 feet high with a 6 foot diameter. Rated at 1000 hp, it will pump liquid sodium at a temperature of 1000° F. and deliver 11,800 gpm against a total dynamic head of 310 feet.

Of special interest are Byron Jackson's engineering accomplishments in designing the pump and installation for "packaged" removal. Basically the pump is divided into two sections—(a) suction tank incorporating suction and discharge nozzles which will be permanently welded into the system, and (b) the complete motor and pump assembly which can be pulled as a unit for routine maintenance and inspection with maximum ease, speed and safety. The "packaged" design even provides for shielding (normally separate from the pump assembly) to be integrated within the pump motor support assembly.

This record-making liquid sodium pump with its special design features marks another step in Byron Jackson's continuing leadership in the liquid metal pumping field.

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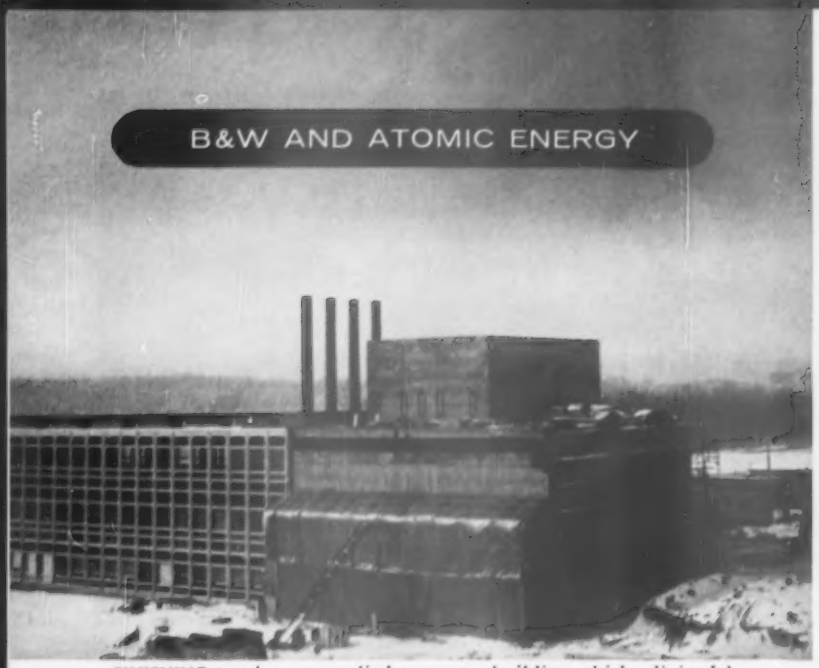
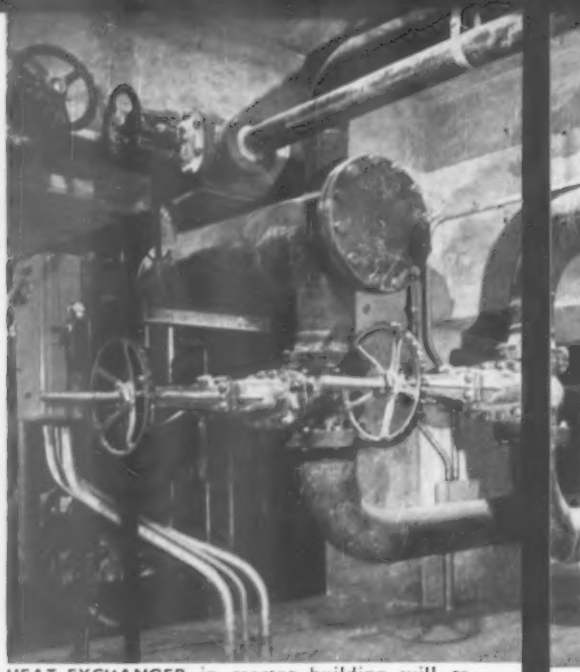


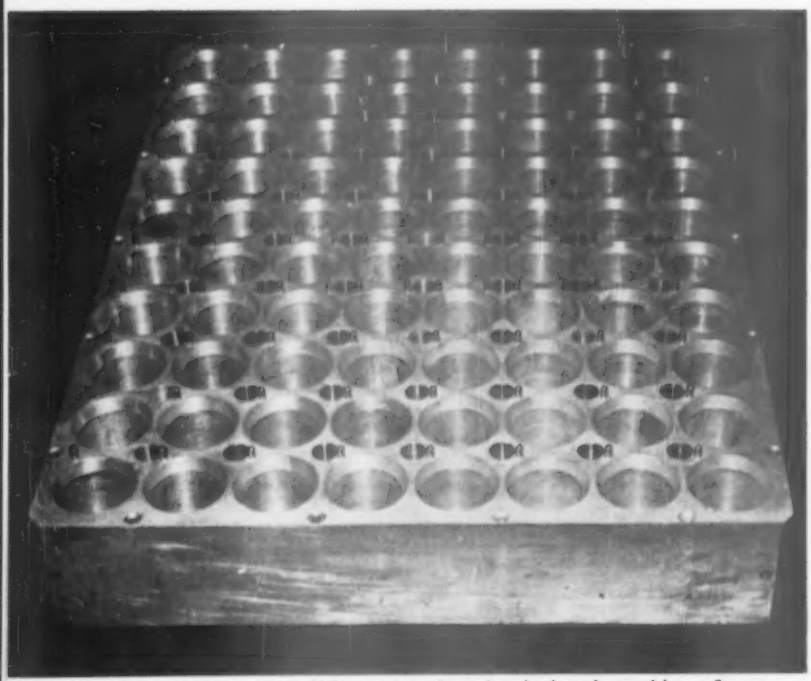
FINISHING touches are applied to reactor building which adjoins laboratory. Doors and building dampers are fitted with gaskets to provide a tight seal when closed.



HEAT EXCHANGER in reactor building will remove one megawatt of heat by forced circulation.

UNIVERSITY OF MICHIGAN LABORATORY ATTACKS

B&W Reactor Putting



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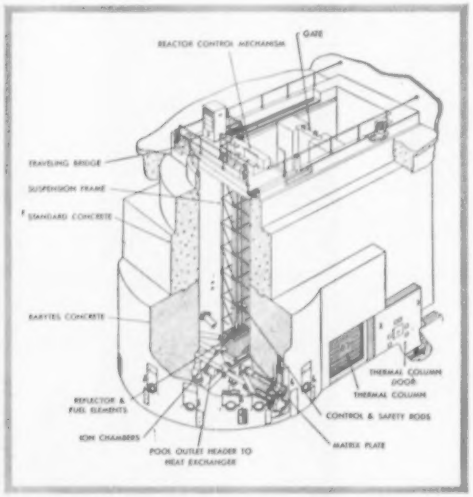
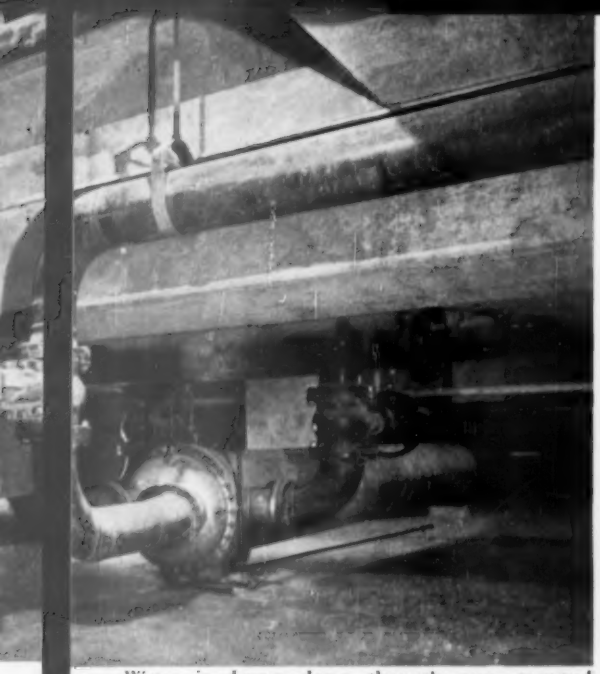
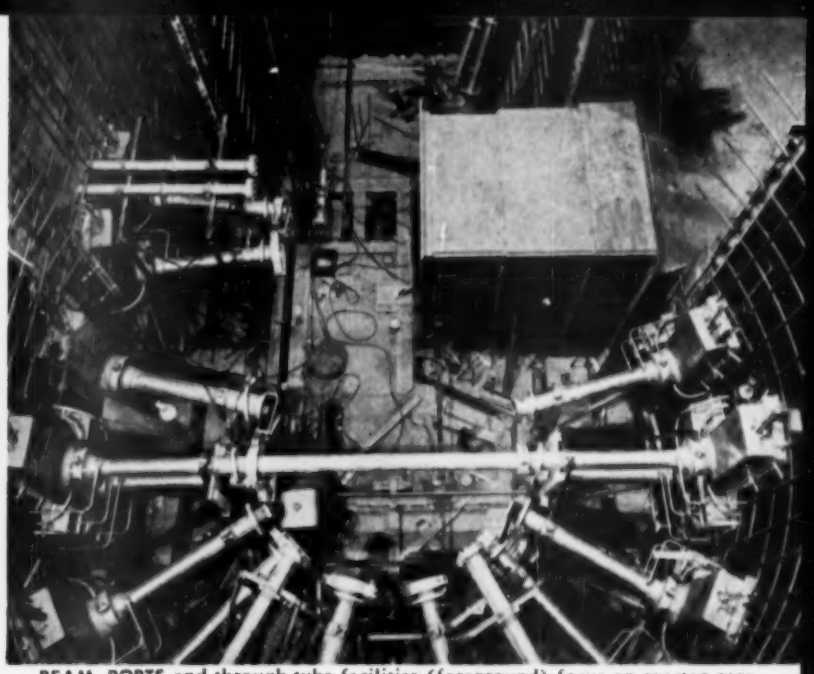


DETAILS of construction of the B&W Swimming Pool Type Reactor at the University of Michigan are shown in the cutaway drawing.



Water is drawn down through core, pumped through heat exchanger, and then returned to pool.



BEAM PORTS and through-tube facilities (foreground) focus on reactor core full-power operating position. Thermal column (upper right) is stacked with graphite blocks to slow down entering neutrons to thermal velocities.

BASIC RESEARCH PROBLEM WITH . . .

Neutrons to Work

tical training in nuclear technology for both engineers and scientists. It will also supply some of the radioactive isotopes for the many studies now employing tracer techniques.

GRID PLATE is in position to support fuel and reflector elements in rounded end of pool. Concrete channels in foreground are for pool gate which is raised by crane to permit passage of suspension frame.

In this design the basic pool-type reactor concept was adapted by B&W engineers to the special needs of the University of Michigan. The equipment components were fabricated and installed by B&W.

FROM THE BEGINNING of atomic energy, at Chicago, Oak Ridge and Hanford, to the application of nuclear energy to steam generation, like the new Consolidated Edison plant soon to rise at Indian Point, B&W has had an important and responsible role in the field of atomic energy. It continues to maintain its leadership by backing its long experience in related fields with a continuing, independent research and development program that studies the implications and the uses of a whole new world of energy.

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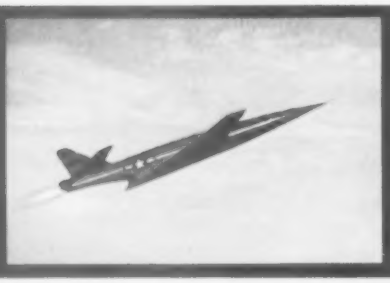

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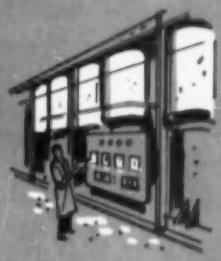

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What alloys creep the least when exposed to continued high heat and corrosion?

To find out, metallurgists use the setup shown. They grip one end of the alloy specimen (*A*) with a fixed rod (*B'*), grip the other with a loaded rod (*B"*) free to move. To measure creep, they periodically gauge separation between collars (*C*) set-screwed to specimen. During the run (often months or years) temperature is carefully controlled.

Hard on specimens . . . harder on the grips and collars

In the test, the alloy used for grips and collars acts as a "gentleman's gentleman". . . stays with the specimen till failure. Then does it again and again with specimen after specimen.

In the 1200° — 1500°F range, Inconel "X"* age-hardenable nickel-chromium alloy is widely used for these grips and collars.

Endurance of alloy leads to its use for nuclear equipment

Wherever highly stressed structurals must function up to 1500°F, Inconel "X" alloy is often specified. It provides 100-hour rupture strength as high as 29,000 psi at 1500°F. It also offers outstanding structural, mechanical and chemical stability; excellent spring properties at temperatures up to 1000°F; high resistance to galling and abrasion; low coefficient of expansion; low creep.

Get a complete rundown on Inconel "X" alloy, its properties and use. Write for 79-page Inco booklet, "Inconel 'X'."

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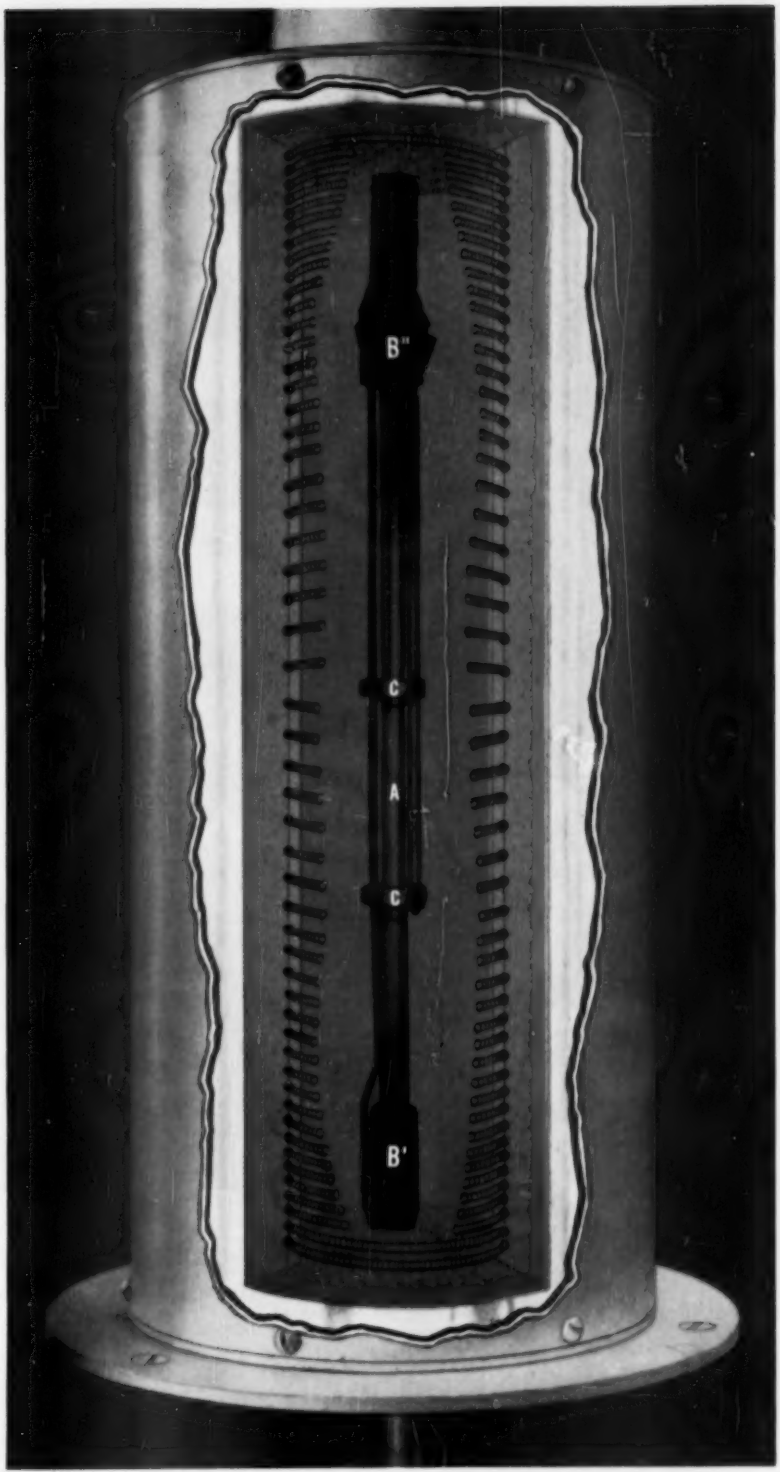
Does Inco make other low-creep high-strength heat-resisting alloys?
Yes! Other excellent Inco Nickel Alloys are produced. Still others are in research. Inco's Development and Research Division will be glad to advise on the use of these alloys. Just write.
*Registered trademark



INCO Nickel Alloys

Inconel "X" *for long stress-rupture life at high temperatures.*

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PRODUCT RESOLVER

— produces a direct current proportional to the product of two varying electrical signals

- four-quadrant operation
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- permanent calibration constant
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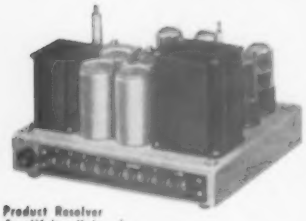
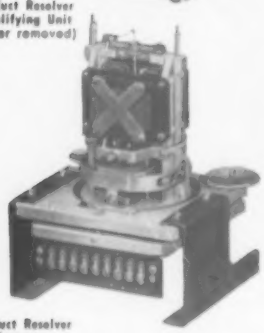


Product Resolver Amplifying Unit (cover removed)



Product Resolver Converter (cover removed)

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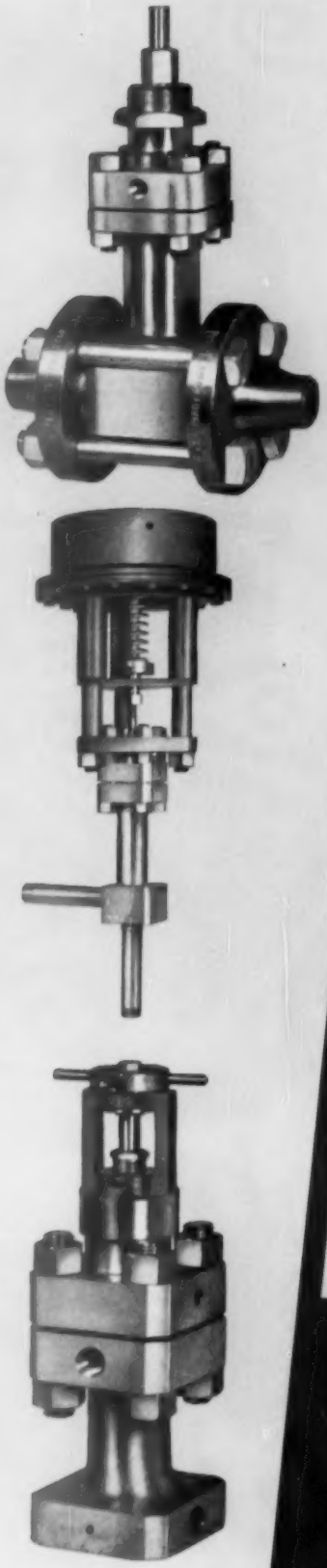
A Daystrom Unit

This Weston Product Resolver employs an electronically balanced electrodynamometer instrument mechanism to develop a product output signal from two input signals by torque multiplication. The Inductronic® balancing system provides precise and rapid response, and an exceptional order of response to displacement. The mechanism is unique to this purpose and stems from Weston's long experience in the design and manufacture of precision dynamometer mechanisms. The complete story on the Model 1482 Inductronic Product Resolver can be obtained from your local representative or by writing Weston Electrical Instrument Corp., Newark 12, N. J., A subsidiary of Daystrom, Inc.



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Some valves are good for severe corrosives, others for high pressures and temperatures, but these Fulton Sylphon Packless Valves are *complete* valves capable of mastering the toughest possible combination of conditions in atomic energy plants and grueling chemical processes. They assure utmost safety in handling hazardous materials, require no periodic maintenance, and practically eliminate down-time.

Typical of how Fulton Sylphon matches valve to process, these valves are made of stainless steel throughout, with the valve body machined as one unit from solid bar stock. And to prevent leakage or contamination, a SPECIAL SYLPHON® BELLOWS in multi-ply stainless steel forms a permanent, leak-proof seal for the stem. That is why they tame the severest corrosives inside and out. This is the reason, too, why these valves provide a high safety factor in high temperature-high pressure service.

These and other Fulton Sylphon Valves are available in many types, sizes, and metals—all with packless construction for greater safety, less maintenance and longer runs "on stream."

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A SPECIAL SYLPHON BELLOWS which forms the permanent, leak-proof stem seal on all Fulton Sylphon Packless Valves offers four outstanding features. It is (1) cold-worked for greater resiliency and longer life, (2) seamless, without welded seams to break and leak, (3) formed in multi-plies for greater strength, and (4) made in the right metal for service requirements.

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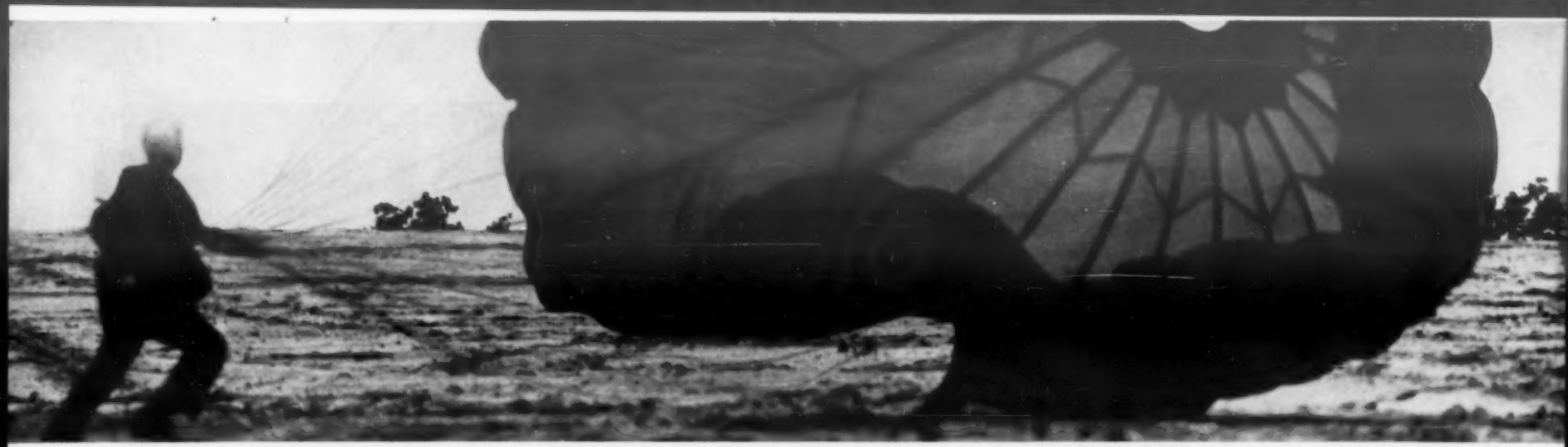

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LOCKHEED'S C-130 HERCULES, NEW PROPJET "STRONGMAN" OF TACTICAL AIR COMMAND'S 18TH AIR FORCE, CAN AIRLIFT MORE FIGHTING MEN AND EQUIPMENT FARTHER, FASTER, AND AT LOWER COST THAN ANY COMBAT CARGO CARRIER NOW IN SERVICE.

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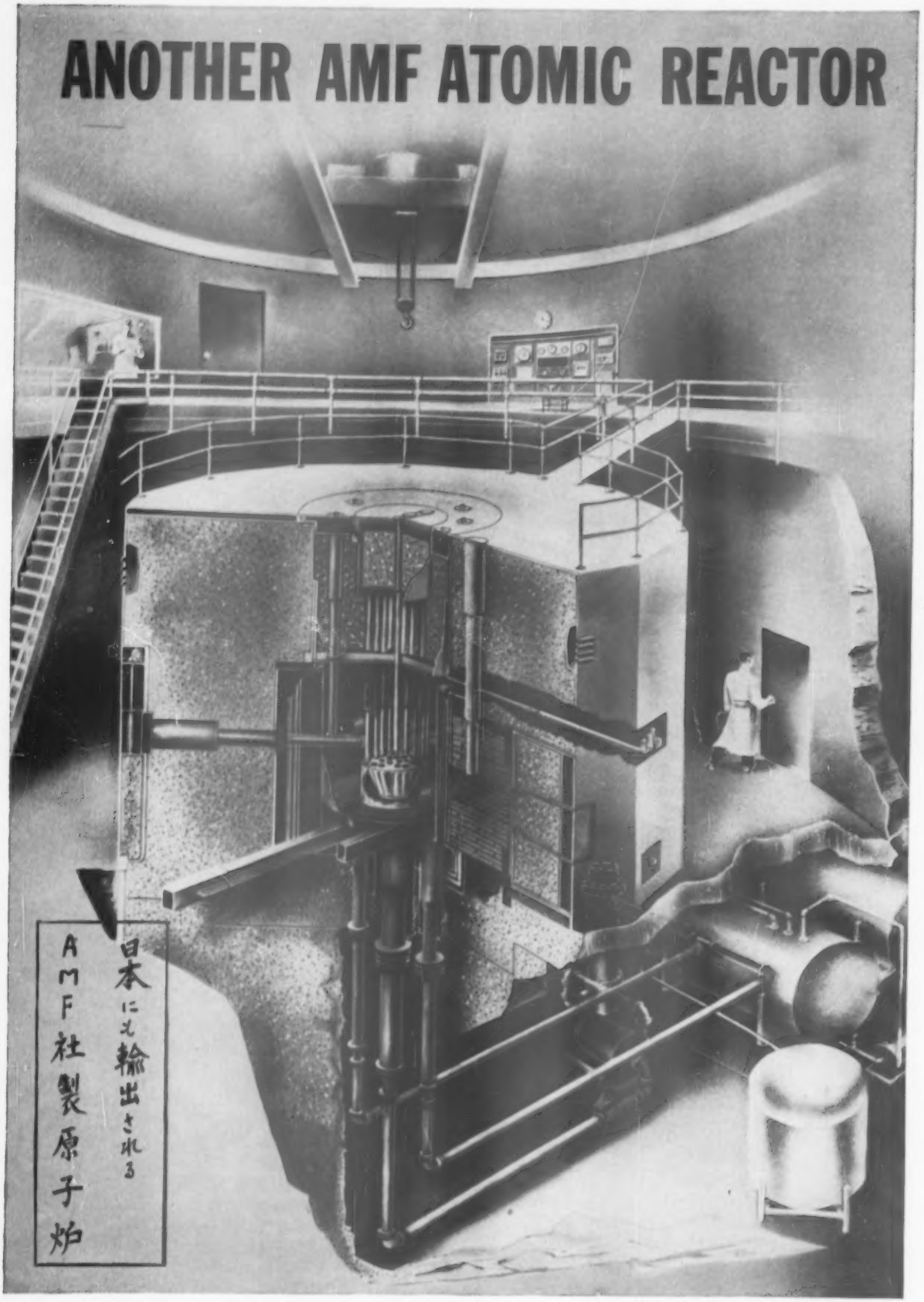
LOCKHEED GEORGIA DIVISION: *(U.S. Air Force Plant No. 6, Marietta, and Georgia Nuclear Laboratory, Dawsonville)* PROPJET C-130 HERCULES COMBAT CARGO CARRIER • B-47 MODERNIZATION • NUCLEAR-POWERED AIRCRAFT RESEARCH & DEVELOPMENT


ANOTHER AMF ATOMIC REACTOR
日本にも輸出される
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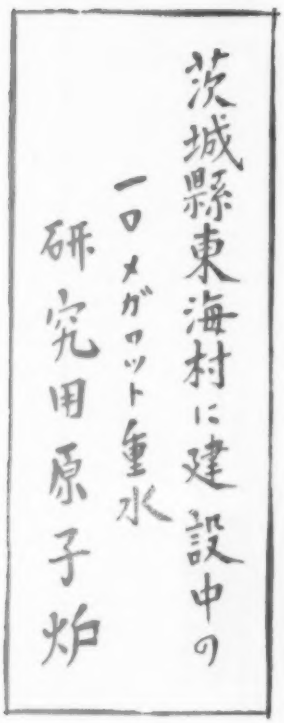
10 megawatt heavy-water research reactor under construction at Tokai-Mura, Japan



The AMF reactor being built for the Japanese Atomic Energy Research Institute is another example of the important role AMF is playing in the development of the peaceful uses of atomic energy throughout the world.

From initial facility planning to final start-up, AMF is assisting research organizations everywhere to build reactor centers that will support both extensive experimental programs and personnel training.

The recognized leader in the design and construction of research reactors, AMF is able to draw upon its extensive experience to provide "Custom Designs", such as the JAERI reactor at Tokai-Mura, at a minimum of cost and delivery time. Many tested design features have been incorporated in the AMF heavy-water system—engineering improvements that have further advanced the safety, versatility, and efficiency of this reactor type. The AMF "Unitized" design approach results in minimum initial costs, greater safety, and simplified maintenance.

Design Features—AMF Heavy-Water Reactor

Power—The AMF heavy-water reactor employs heavy water as coolant, moderator, and reflector. The usual graphite reflector has been eliminated, and a special thermal shield consisting of alternate layers of steel and light water has been incorporated, permitting higher power levels than would otherwise be possible. The higher neutron flux densities are often required for radiation damage studies, isotope manufacture, many in-pile experiments, and solid-state physics work. The AMF heavy-water reactor offers standard power levels of 1, 2, 5, and 10 megawatts, with still higher power levels possible. Flux densities range from approximately 1.4×10^{13} at 1 mw. to 1.2×10^{14} at 10 mw. with 20% enriched uranium. With fully enriched fuel operating at 10 mw., flux densities of 2×10^{14} can be achieved.

Control—Control rods are of the vertical rather than the semaphore type. They are thus not only easily removed for servicing, but provide an even control effect that is directly proportional to control rod movement. Both the mechanical and electronic portions of the system are of the same AMF design that has proved safe and reliable in research reactors now in actual operation both here and abroad.

Safety—All elements of the design have been pointed toward providing the greatest safety possible. Among the numerous safety features included are a dump valve for automatic or manual lowering of the heavy water, which eliminates the vertical reflector. In the event of pump failure, a natural convection path is automatically opened to provide emergency cooling.

A rotary top plug and semi-automatic refueling cask have also been incorporated to provide for safe, easy refueling, eliminating the need for an individual opening and seal for each fuel element.

Facilities—A total of 30 individual experimental facilities are included in the AMF heavy-water reactor. 11 beam tubes, 2 horizontal through-tubes, 2 isotope trains, 4 pneumatic tubes, 10 vertical thimbles, and a thermal column permit an exceedingly wide range of experimental activities. Motor-driven vertical shutters provide convenient access to the horizontal beam tubes. And with AMF's unitized design, these reactor facilities can easily be modified to meet specific research requirements.

For a complete reactor facility, from first plans to final start-up, or merely for reactor components, contact AMF. You'll find AMF Atomics has both the *experience* and the *fully proven technical ability* to assist you in all phases of atomic energy involving research or power reactors and facilities.

See booths 117–21, 3rd ATOMIC EXPOSITION, March 11–15, Convention Hall, Philadelphia

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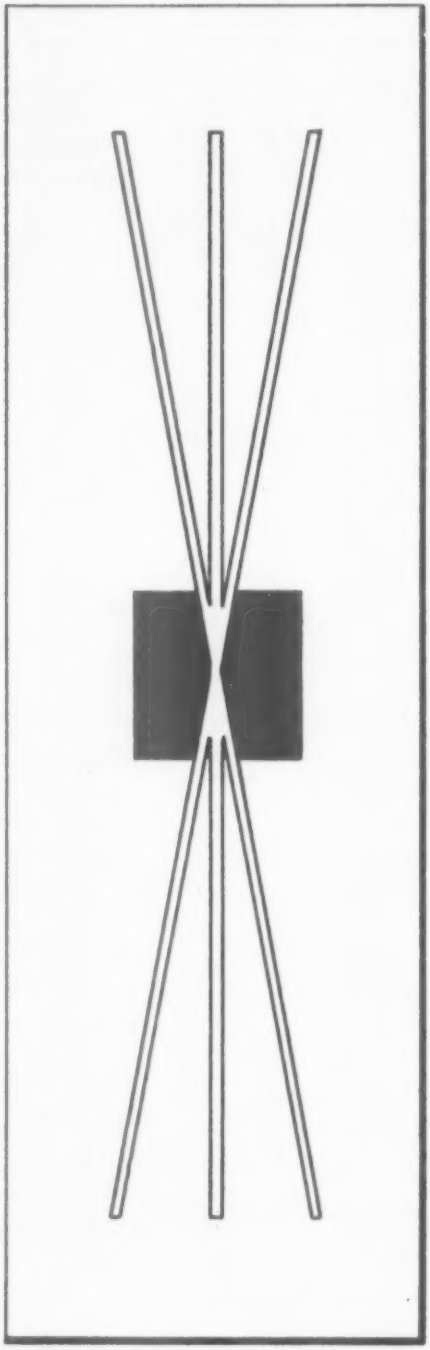
AN ENGINEERING TEST REACTOR by NDA

The engineering test reactor now in the design stage at NDA for construction and operation at Mol, Belgium, in 1959, will provide experimenters with a new and higher degree of flexibility and freedom for the conduct of complex experiments at high neutron flux. Ready access to experimental regions during reactor operations is provided.

This test reactor, the first of its type, known at Mol as Belgian Reactor II, will be a major addition to the facilities of the Centre d'Etudes pour les Applications de l'energie Nucléaire.

NDA has been joined by senior C.E.A.N. personnel in detailed design, engineering, and development of this unit. Included in the NDA-C.E.A.N. team are experienced experimenters familiar with the difficulties encountered in conducting experiments in other types of research and test reactors.

NDA will continue to assist C.E.A.N. through construction and test operation of this engineering test reactor in order to add U.S. experience to the abilities of C.E.A.N. and Belgian industry.



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ROUNDUP of Key Developments in Atomic Energy

Congress, Industry Reviewing Reactor Program

Adequacy of our power reactor program promptly again became the central theme of the third annual industry hearings before the Congressional Joint Committee on Atomic Energy. And any hope that the contentiousness that ruled relations between JCAE and AEC last year would be dispelled proved forlorn: within an hour of the opening of the hearings, Committee Democrats were trying to elicit from Commission witnesses evidence to support their position that private industry cannot be expected to develop competitive nuclear power without massive financial aid from the government. The Gore bill debate had broken out again.

In an effort to streamline proceedings, AEC submitted its account of its stewardship this year in written form (293 pages) for the record, and contented itself orally with a 55-minute summary by Chairman Strauss. However, just as in past "202 hearings" on the growth, development and state of the atomic energy industry, Committee members were at once probing for weak spots in Commission programs and policies.

What Worries Congress

Costs. It has suddenly become apparent that, far from yet beginning to approach competitive levels, nuclear power costs are headed in the opposite direction—up (*see story p. R5*). Inflation and escalation have reared their ugly heads in the atomic business, and this buttressed the feeling of many Congressmen that private enterprise cannot be expected to rush in to lose money. Owing to the increase in capital costs at Shippingport, power from PWR's first core will cost 75, not 52 mills, Sen. Anderson said, and will later come down to 30.

Foreign markets. The U. S., competitive position, particularly vis-à-vis Britain, came in for extended discussion. Some found reassurance in the fact that U. S. manufacturers hold six firm contracts for sale of power reactors outside the country—six more than any other country has; and that since filing of the Ishikawa report in Japan (*see p. R4*), the Japanese have apparently decided to send another, reappraising survey team to the U. S. and U. K. In spite of this, considerable feeling was expressed—by Senators Anderson, Pastore, Gore, Representatives Cole, Holifield, Price, among others—that more could be done by the government to aid U. S. industry in competing on the world market. Atomics International's general manager Chauncey Starr called for a positive program to support the development of the U. S. nuclear equipment industry in the export field. NUCLEONICS editor Jerome D. Luntz told JCAE, "We have failed to do an adequate job of selling our accomplishments, failed to excite the imagination of the peoples of the world . . . Now is the time for the U. S. to strike out in the international field with a plan that has boldness of purpose and implementations." He offered a five-point program, including stepped-up work on technology of interest abroad, such as natural U fuel; assure long-term continuity of supply of enriched fuel; build a large test reactor for exclusive use of foreign countries; bold support of Euratom and Japanese power programs, and bolder declassification. Likewise, AEC Commissioner Vance said we "should be in a position to promise necessary fuel supplies [abroad] for a longer period than 10 years. I think it should be at least 20 years, better 25."

Classification. Whether the problem of classified information has, as AEC contends, been ended by the new declassification guide, came in for review. No answer is likely until the review of papers in the light of the new guide has been carried out. Nevertheless, study of the areas announced as being henceforth declassified reveals gaps: AEC still holds secret the price of depleted U, necessary for complete analysis of fuel cycle economics;

New core design for Con Ed: higher power, higher price

Babcock & Wilcox has designed a new core for Con Edison's Indian Point nuclear power station. It will raise the power level from 236-Mw to 275—163 of this from the reactor, 112 from the oil-fired superheater. The seed-and-blanket concept has been abandoned, and there will be a large, and at first uniform, core of Zircaloy-2 tubes containing 97% thorium oxide and 3% uranium oxide at top enrichment. The tubes will be tied into bundles 6 in. square. The oxide mixture may be formed into sintered pellets, or fabricated by a promising alternative method now being explored by B&W. The new core was adopted because of radiation damage data on metallic Th and U-Zr alloy plates developed by B&W. It involves no change in time schedules. The project is in midcourse, Con Edison's Board Chairman Hudson Searing reported. Initial shop fabrication has started on the reactor vessel and four primary coolant steam generators, and procurement has started on primary coolant pumps and valves and other major components. Within six months detailed design will be completed and procurement started on control rod drives, primary coolant piping, pressurizer, and containment structure. A spherical containment shell, not earlier provided for, has been adopted; it will be half underground. Bailey Meter Co. has been chosen to supply all plant and nuclear instrumentation. A full-scale in-pile loop to irradiate fuel materials is nearly complete at MTR and is scheduled to start operating this month, as is a full-scale critical experiment at B&W's Lynchburg plant. Cost of the plant is now estimated at $70- instead of $55-million, because of these design changes, increase in materials cost and in plant capacity. This will raise capital cost to $255/kw, power cost to 1.2¢/kwh.

fuel reprocessing costs and how they are arrived at, etc.

What Bothers Industry

Indemnity. Nearest thing to unanimity at the hearings was the way industry called for action on the bills providing $500-million government indemnity coverage for nuclear hazards—the measure that just failed of passage last year.

Patents. There is insufficient protection in foreign countries for inventions by Americans, as contrasted with foreign governments' aggressive patent policies outside their borders.

Classification. Many industry witnesses urged complete declassification of all reactor technology except such information on military reactors as is peculiar to their military application. Witnesses ranging from Prof. V. L. Parsegian of Rensselaer Polytechnic Institute to the National Association of Manufacturers called for an end to the concept that information is "born classified."

Fuel reprocessing. Uncertainty about the availability of chemical reprocessing services, of knowledge about their circumstances and costs, were cited as obstacles by Willis Gale of Commonwealth Edison, Francis McCune of GE, William Webster of Yankee Atomic and others.

Minority View

Commissioner Thomas E. Murray, consistent dissenter in the Strauss-led AEC, again presented minority views on the efficacy of our power reactor development policies. "There has been too much salesmanship and not enough engineering in nuclear power," he charged. " . . . it is premature today to believe that the economic merit of power reactors can be evaluated realistically. As this understanding becomes more widespread it should lead private industry generally to welcome the assistance that a government program of large reactor construction can give." Murray urged such a program of large-reactor building on government sites, in addition to efforts under the third round of the Power Demonstration Reactor Program, holding that this would provide vital initial information for industry, help reduce costs, lessen the risk that private industry's plants would fail, and speed up technical progress.

Commissioner Willard F. Libby replied that the specific large-reactor types espoused by Murray are already covered by present or future AEC projects; that available technical manpower is inadequate to carry out such a program, and that locating large experimental reactors where base-load stations are needed is poor economics.

AEC Disclosures

Much of the mass of written testimony by AEC describing its activities had previously been reported in the 21st semiannual report (NU, Feb. '57, R1). Some new items:

- Bilaterals. Preliminary discussions have been held on research agreements with Ceylon, Haiti, Liberia, and South Africa; on power agreements with Argentina, Brazil, Cuba, Germany, India, Iran, Israel, Italy, Japan, Pakistan, Philippines, South Africa, Spain, Sweden, Thailand, Tunisia, Uruguay. Most of these countries are reviewing draft agreements.
- HRE-3. Although it had been hoped a slurry blanket could be tried in HRE-2 in place of a D_2O blanket to be used initially, this does not now seem feasible. Plans are underway for a third experiment, HRE-3, utilizing a slurry of thorium oxide for the blanket.
- LAMPRE-1 will work at 1,100° F, is to start up next year.
- Isotopes. Libby reported industrial isotope savings are now at about $400-million/yr, may hit $500-million by 1958 or 1959.

15,000 Mw by 1967 is Euratom's Goal

A nuclear power program so ambitious it caused gasps of surprise even in big-thinking America was broached by Euratom as the six-nation European Atomic Energy Community came to life.

The U. S. government promptly gave its official blessing to the plans to install 15-million kw of nuclear power in Western Europe by 1967—3,000 Mw/yr for five years beginning 1963. Washington promised to supply nuclear technicians to help get what it called "a bold and imaginative application of nuclear energy" underway, and to supply nuclear fuel in the future.

The program and the U. S. pledge were announced simultaneously in Washington Feb. 8 as the "three wise men of Euratom"—Louis Armand of France, Franz Etzel of Germany and Francesco Giordani of Italy—concluded talks there with U. S. officials. Just 12 days later in Paris the premiers of the six Euratom nations—France, West Germany, Italy, Belgium, Holland, Luxembourg—agreed on the basic provisions of a treaty whereby they will pool their nuclear resources under a European Atomic Energy Commission. The treaty itself is to be signed in Rome this month. Decisions and commitments on such things as kinds, amounts and prices of fuel, procurement terms, etc., will follow ratification of the treaty, expected by summer. Meanwhile, technicians of Euratom and the U. S. will be laying the groundwork for those decisions.

Europe's Need

If carried out, the Euratom program would make Western Europe the leading nuclear power center in the world within 10 years. The 15-million-kw-by-1967 goal compares with U. S. plans to build about 1.8-million kw by 1962, an expanded British program for about 6-million kw by 1965, and an announced Soviet goal of 2.5-million kw by 1960. The Euratom goal is the equivalent of 163 Calder Hall reactors, 250 Shippingport plants.

However it is a grim, inescapable economic reality that decreed this goal: the six nations imported 6% of their fuel needs in 1938, 25% (100-millions tons/yr coal equivalent) in '56; projected, this means 35% (200-million tons) in 1967, 45% (300-million tons) in 1975. And then there is Suez.

Nuclear power offers a possibility of checking increasing dependence on imported fuel—and the 3-million kw/yr figure is actually the nuclear capacity required to meet increasing energy demand and stabilize net fuel imports at the level reached when the nuclear program begins to take effect: 1963.

Moreover, Euratom can transform the face of European industry, by making it possible to build a considerable nuclear capacity quickly—which the six nations individually cannot. And by leading to a practical solidarity of interest among the six nations, it is a long step toward the dream of a United States of Europe.

U. S. Stake

This certainly assured the welcoming U. S. attitude, for Washington has long regarded European unification as essential to the strengthening of the Atlantic community. And with the Suez situation and the U. S.' new responsibility for stabilizing the Middle East, it is in our interest to help Europe develop alternative power resources. But

there are nuclear as well as political advantages.

Large-scale European A-power development will provide a unique and invaluable proving ground for U. S. nuclear industry. It has already become a truism in the field that nuclear power will be competitive much sooner in Europe than in the U. S. because present conventional power costs are so much higher abroad. To U. S. industry, therefore, Euratom looms as a big demonstration program extended overseas; by participating in its plans, American manufacturers can gain experience, prove out prototypes, and develop their industrial base while awaiting the dawn of the nuclear power era at home. This could provide what some Europeans see as the missing ingredient in the U. S. reactor program: a sense of focus and of urgency.

This is not to say that U. S. industry can sit back and expect the lion's share in building Euratom's 15-million kw capacity. True, in the first phases of the program, Euratom planners expect to obtain half their reactors in the U. S., half in Britain. But all six Euratom nations are highly industrialized, five of them with positions in the world market to defend, and it is no secret that they will take over a growing share of component and reactor building as rapidly as they can.

Euratom's Role

Contrary to some misconceptions here, Euratom will not itself be building power reactors. Rather it has a "shepherd function"—to try to open eyes in the member nations, awaken people to think big. "If we do," says one spokesman, "we might have 25-million instead of 5-million kw in the 1960's—there's that much difference." The operations Euratom will undertake are those that lend themselves particularly to large-scale, cooperative handling, like fuel fabrication and chemical reprocessing. Euratom is empowered to build power stations, but plans to do so only *in extremis*, if the program falters.

Euratom's leaders attach great importance to AEC's offer of immediate technical help. This means the next six months—a time of waiting for the treaty to be ratified and personnel to be appointed and organized—need not be lost: the technicians can get started on predesign work on health and safety, inspection, and waste disposal regulations; on specific technical problems like plutonium recycling; and on determining what accommodations in the six countries' laws must be made. Some feel the most important task thereafter will be to get a few representative full-scale stations built, and one idea already bruited is to have four plants—a pressurized water, a boiling water, a heavy-water-moderated and a Calder-type—built on the same site.

Uranium Inventory

The fuel required for so massive a program can be roughly calculated to be about 6,000 tons/yr of natural uranium; exact amounts of course will depend on reactor types chosen. Euratom members produce about one-third this amount themselves. It is felt likely that Euratom may import about 12 tons of U. S. contained U^{235}/yr, at a possible cost of some $200-million—but imports of U. S. coal alone this year run about $800-million. Thus, although capital cost of installing 15-million kw of nuclear power is estimated to cost $2-billion more than the same amount of conventional capacity, once installed, the initial fuel costs are only about one-fourth as much.

Comptroller General hits AEC-Yankee contract

The General Accounting Office has loosed a broadside at AEC's first contract under the Power Demonstration Reactor Program—that with Yankee Atomic Electric Co. Criticisms were: first, that the 12 utilities owning Yankee had not yet executed binding agreements with Yankee covering their proposed capital contributions to the company and their purchase of power from it; therefore, "Yankee has not demonstrated its financial competence" and AEC "executed the contract without adequate assurances that the Government will receive benefits commensurate with its investment." Second, that neither Yankee nor its 12 sponsors have given contractual assurance that Yankee will perform the work called for—to which AEC replied that the amounts being invested are so substantial a decision to abandon would not be taken lightly. Third, that AEC does not have the right to audit all Yankee costs including those AEC does not bear—but should have, as the greatest return to AEC is expected to be economic as well as technical data on building and operating full-scale plants.

Comptroller General Joseph Campbell, himself a former Atomic Energy Commissioner, laid down ground rules for future contracts between AEC and industry for demonstration reactors, and told the Joint Congressional Committee on Atomic Energy that AEC General Manager Fields had agreed to adopt them in pending and future contracts. These provide that AEC require binding agreements from sponsors of a contracting party covering their financial contributions to the project, guaranteeing that the work will be performed, and assuring AEC's right to audit all transactions related to the contract.

AEC offers reprocessing service

Pending entry of private industry into the field, AEC has established chemical reprocessing services for operators of private reactors. Individually negotiated contracts will establish firm charges, subject to escalation on the basis of an appropriate price index; possible range of prices was not disclosed. Contracts will be subject to cancellation by AEC on six months' notice if similar services become commercially available at reasonable prices. The AEC service will include waste disposal.

General Electric starts destroyer propulsion project

GE's Knolls Atomic Power Laboratory has started development work on a pressurized-water reactor plant for a destroyer-class ship. The project is designated DIG. GE is working on a pressurized water system, the Submarine Advanced Reactor, for the twin-reactor sub *Triton;* and is phasing out work on the sodium-cooled *Seawolf* reactor.

Buy British, Japan Urged; 5 Utilities Have A-Plans

The Ishikawa mission, which visited the U. S. and Britain last summer, has recommended: "While taking future developments in the U. S., etc., into full consideration, it is advisable that the first step to be taken by our country should be to introduce a British-type power reactor, a large prototype of which has been completed and for which the technical and economic problems involved can easily be explained." The report urges a size between 100 and 150-Mw, asks that the British Atomic Energy and Central Electricity Authorities be asked to furnish detailed information on fuel factors, graphite efficiency, etc.; and that then experts be sent to Britain again to consult on uncertain details, financial arrangements, and fuel supply.

Of the U. S., the report states, "In the last analysis, it is considered that the U. S. is really in the lead of the world in the field of accumulated knowledge and experience in nuclear energy with respect to the scale, the amount of investment made, and the number of important staff personnel. As far as the generation of electric power by nuclear energy is concerned, however, it is considered premature to introduce in the immediate future a large-size power reactor for practical purposes [from the U. S.], although their future possibilities are considered great and the time will come for their future introduction into our country in view of the fact that power reactors now being developed in the U. S. using enriched uranium have an advantage [over other types] in permitting freer designing of power reactors . . ."

Japanese Industry Active

Five of Japan's 10 electric utilities are studying plans to begin atomic power generation:

• Chobu Electric Power Co. is expected to complete plans by May for a 100-Mw natural uranium reactor.

• Tokyo E.P. Co. has already completed a blueprint of a 10-Mw reactor.

• Kansai E.P. Co. is preparing to build a two-reactor, 10-Mw plant—with one heavy-water, one light-water unit.

• Hokkaido E.P. Co. contemplates a 50-Mw pressurized water reactor.

• Kyushu E.P. Co. has decided to order a 150-Mw reactor abroad this year.

Also, Mitsubishi Electric Mfg. Co. is reported planning to build a pressurized water reactor with technical aid and parts from Westinghouse.

Koichi Uda, new chairman of the AEC and State Minister in charge of the Economic Planning Board, says 3,000-Mw of nuclear capacity should be installed in Japan by 1962.

Nibbles on the International Market

Activity reports from the international reactor market were frequent last month. Here are some:

• Sir Thomas Playford, premier of the state of South Australia, is reported to have had talks with U. S. diplomatic representatives concerning possible U. S. aid in obtaining a power reactor. The government of South Australia wants to build a small power plant at Mt. Gambier, a trading center and rail junction between Melbourne and Adelaide in the southeasternmost corner of South Australia. The state government is reportedly trying to get an Export-Import Bank loan for purchase of a U. S. reactor.

• The London *Evening Standard* has reported that three Italian industrial groups have contacted the four main British nuclear syndicates seeking estimates on a 100-Mw natural uranium power plant for Italy. Replies are due this month. It's believed the cost of such a central station will amount to about $42-million, of which $28-million would be spent in Britain, $5-million in Italy on accessories and buildings.

• India's Trombay Atomic Energy Establishment is reported to have contacted "a British firm" that recently announced it was ready to sell 10–20-Mw pressurized water power plants. This would be Humphreys & Glasgow Ltd., as licensees of Alco Products Inc. (NU, Feb. '57, R4). Meanwhile, Madras and Ahmedabad are vying to get the first large Indian power reactor, announced by Homi Bhabha (NU, Feb. '56, 15; May, 142; Feb. '57, R11).

• Top Finnish nuclear scientists have met to discuss purchase of a research reactor, and the Institute of Technology has submitted firm proposals to the Ministry of Trade and Industry for a 1-Mw unit of undetermined type and make. $43,000 is asked for training and study on installing and operating it, and $345,000 as a down payment. A member of the technical physics department of the Institute has gone to the U. S. to look at American reactors. The Institute has asked and received many offers from U. S. and British firms; most promising—in delivery time and price—is reported to be that of Babcock & Wilcox of New York. Also, Erkki Aalto, new director-general of the Finnish State Railways (and chairman also of Atomic Power Inc., founded last year) has announced he sees a use for nuclear power in connection with large-scale rail electrification plans just starting to be carried out.

Organic hole in ground

Reactor tank for Organic Moderated Reactor Experiment is lowered into cavity liner sunk into earth at Idaho testing station (sketch NU, Aug. '56, 42). Tank is 28 ft high, 56 in. dia. OMRE, being built by Atomics International (NAA) for AEC, will produce 16-Mw heat, to be dumped. OMRE is now near completion; only control rods, instrumentation, part of organic fluid heat transfer piping remain to be installed

Union Carbide Building Big N. Y. Research Center

A nuclear research center will be built in Sterling Forest near Tuxedo Park, N. Y., 40 mi NW of New York City, by Union Carbide & Carbon Corp.

It will feature a 5-Mw pool research reactor to be built by AMF Atomics. Other major facilities will include a radioactive materials lab, an ores and engineering lab, and a building for allied research operations and administration. Research programs will be geared to the study of radiation effects on products and processes involving plastics, gases, metals, carbons and chemicals. Completion of the center is set for late 1958 or early 1959, the first of several research centers planned for the Sterling Forest area.

How Nuclear Power Plant Costs Have Been Rising

Members of the Congressional Joint Committee on Atomic Energy brought out during the industry hearings that original capital cost estimates on nuclear power station projects underway have been rising fast. Here are some figures:

PWR, Shippingport—up from $37.5-million to $55-million.

Con Edison, Indian Point, N. Y.—up from $55-million to $70-million.

Consumers Public Power District, Hallam, Neb.—up from $24.3-million to $40- or $50-million.

Wolverine Electric Corp., Hersey, Mich.—construction cost estimates up 25%.

Rural Cooperative Power Assn., Elk River, Minn.—reactor and superheater cost alone up $2-million from $3.7-million original maximum estimate (total plant cost up $2-million from $6.39-million).

Yankee Atomic Electric Co., Rowe, Mass.—up from $35-million by "a substantial margin" not disclosed, but estimated by NUCLEONICS at about $6.3 million.

Commonwealth Edison, Dresden Station near Chicago—"GE entered into a contract at $45-million," said Sen. Anderson; "I imagine they are sweating a little bit at the present time."

Hilberry Confirmed As Argonne Director

Norman Hilberry, deputy director of Argonne since its founding in 1946 and acting director since the resignation of Walter H. Zinn last June, has been named director. He has had 15 years of administrative experience in the development of nuclear energy. "After a thorough search for a successor to Dr. Zinn, we came finally to the conclusion that Dr. Hilberry is the man best qualified," said Chancellor Lawrence A. Kimpton of Chicago U. which operates Argonne for AEC.

Five Firms Bid to Build Liberty Ship Gas Turbine

Five of 16 firms asked have answered Maritime Administration's invitation to bid on building a closed-cycle gas turbine propulsion plant for a Liberty ship (NU, Dec. '56, R1). Bidders were Curtiss Wright, General Dynamics' Electric Boat division, Nordberg Mfg. Co., John Roper Associates of Baltimore, and Westinghouse. The plant, to be "reliable and satisfactory" at 20,000 shp, will be used aboard a Liberty with an oil-fired heat source, but is "also required to be suitable for future use with a nuclear heat source."

AFTER SOME fifteen months' illness of cancer, death came to Atomic Energy Commissioner John von Neumann, 53, in Walter Reed Army Hospital in Washington. Recognized as one of the world's greatest mathematicians, he was best known as "the brain behind the electronic brain," the world's leader in developing and building today's high-speed computing machines; and as principal architect of the new branch of mathematics that affords a mathematical approach to economic behavior, social organization and military strategy. Perhaps less widely known is his work as one of the architects of the atomic age: by his fundamental contributions to quantum mechanics, on which all calculations of the behavior of matter are based, he helped lay the foundations for knowledge on how atomic energy can be employed. His colleagues on AEC mourned his death as "an irreplaceable loss to the Commission, to science and to the nation."

First IAEA Conference Set for Vienna This Fall

Vienna will be the scene of the first General Conference of the International Atomic Energy Agency, the IAEA Preparatory Commission has decided. The date is not set, depending on the time a sufficient number of countries ratify the Agency statute adopted in October (NU, Oct. '56, R2; Nov., R3); but it's hoped to have it this fall, perhaps in September. Eighty of the 81 nations who participated in the statute-drafting conference in New York have signed the document and are eligible to become initial members of IAEA; for the statute to come into force, 18 must ratify, including at least three of the "atomic Big 5" (Canada, France, USSR, U. K., U. S.). However as the Board of Governors will have 23 members, a larger number of ratifications is obviously needed to make the statute work. In a surprise move, Russia last month became the first nation to ratify.

The 18-nation Preparatory Commission under Carlos Bernardes of Brazil has been meeting in New York, is working on a draft treaty defining the relationship between IAEA and the U. N., the Agency's first-year budget, and on naming the members of the first Board of Governors—which it must do 60 days before the first General Conference meets. It has set up a six-member headquarters committee to confer with the Austrian government (Vienna was recommended by the conference last fall, but this must be confirmed by the General Conference). A committee of 18 senior technical experts representing each of the member nations of the Preparatory Commission were to meet in New York early this month to begin substantive work.

BNL Starts Reloading; Schedules Lengthened

Refueling of Brookhaven's air-cooled reactor (NU, Aug. '56, 51) has been started; 35 central channels—5% of full loading—contain the new enriched elements, as a test to yield operations data needed for the full conversion. The maximum thermal flux is now greater than 10^{13} but only over a small volume of the moderator. The higher flux will require one day's cooling of irradiated items before removal; consequently, a new shutdown schedule goes into effect March 15, on a 14- instead of 10-day basis, with down time every other weekend.

Boron-10 Production Up, Available to Civilians

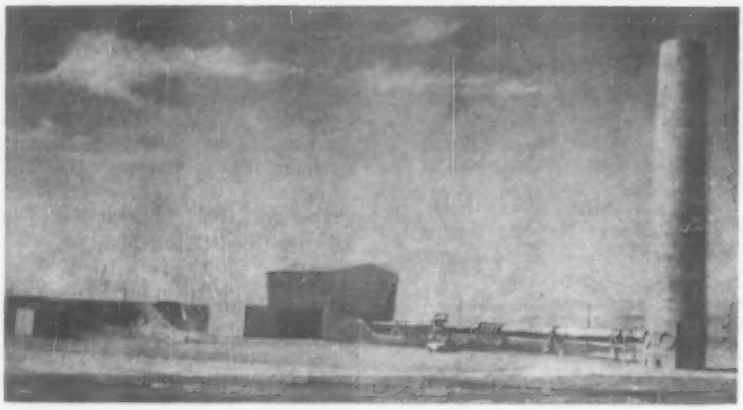
Kilogram amounts of boron-10 are now available to civilian purchasers, AEC has announced, declassifying its $4-million B^{10} plant at Model City, N. Y., 12 mi from Niagara Falls. Operated by Hooker Electrochemical Co., the plant is now turning out 20 lb/wk. It is capable of producing enriched boron at assays from 30% to 95% B^{10}; prices range from $0.85 to $5.30/gm, depending on enrichment, for the dimethyl ether boron trifluoride complex; from $1.25 to $5.65/gm for potassium fluoborate, and from $3.10 to $8.60/gm for boron metal, plus handling and transportation.

Having the property of readily absorbing neutrons without itself becoming radioactive, B^{10} is in demand for shielding, control rods, and radiation measurement instruments. However boron exists in nature as a mixture of two isotopes: only 19.8% is B^{10}, the rest is B^{11} which is not neutron-absorbent. Thus the same separation problem arises as with uranium.

Only full-scale plant producing B^{10} in North America, the Model City works started operation in June 1954 in a converted boiler house of the Lake Ontario Ordnance Works' TNT plant. However until now only gram quantities of B^{10} have been available for civilian purposes.

The separation process used at Model City is as follows: first gaseous boron trifluoride is mixed with dimethyl ether, purified and pumped through a series of six monel distillation, or fractionating, columns—five 65 ft high, the last 25 ft—connected in series to give the same effect as a single column 350 ft high. Continuous recycling abetted by heat, cooling and vacuum tends to concentrate the B^{10}-containing liquid at the bottom of the sixth column, the B^{11} in the first. After the enrichment has been carried out, potassium fluoborate is precipitated from the liquid complex. Finally the salt is fed to five electrolytic cells where boron metal is encrusted on the cathode. After scraping, drying, grinding, leaching and screening, the B^{10} is shipped in polyethylene bags inside gallon tin cans.

Use of B^{10} has to date been largely limited to alloying with steel to make boron steel, or compounded with carbon to make boron carbide, or mixed with other materials, for use in control rods.



First Photo of Atomic Turbojet Site

Tight secrecy on nuclear plane project has relaxed enough to clear this view of initial test area where in January 1956 a turbojet engine was for first time powered exclusively by reactor heat (NU, Aug. '56, R1). Site is at Idaho reactor testing station, where General Electric operates aircraft nuclear propulsion facilities. Construction of additional new facilities has again been announced by AEC. Nevertheless. . . .

. . . Atomic Plane Project 'Stretched Out' Again

Clifford C. Furnas, Assistant Secretary of Defense for research and development, officially confirmed what had long been unofficially affirmed: that the nuclear airplane program had once again been "stretched out"—"for technical reasons." Furnas said "we originally were a little optimistic" on the program, and implied that engine weight and shielding were the main "technical reasons" for again putting off the target date. A practical A-plane is "several years off," he said.

Nuclear Navy News: Busy Month for Growing A-Fleet

• **First cruiser.** The first nuclear-propelled cruiser, world's first atomic surface ship, will be named U. S. S. *Long Beach* for the California port, the Navy announced. She will be armed with Regulus II, Talos and Terrier guided missiles. Her cost is now put at $300-million, $100-million less than first estimates; this is because of better know-how in nuclear ship construction and closer evaluation of all figures, according to Navy Bureau of Ships' Chief, R. Adm. Albert G. Mumma. The cost will continue to come down, he adds, as more nuclear knowledge is acquired. The keel for *Long Beach* has not yet been laid, Bethlehem Steel's Fore River shipyard says.

• **Carrier program.** The first carrier will have 32 heat exchangers, four for each of its eight reactors. It is scheduled to join the fleet in 1961. Last month the Navy asked Congress for five more to follow it, one a year, for a total of six 80,000-ton nuclear carriers in service by 1966.

• **Nautilus,** submerged, passed the 60,000-mile, or 20,000-league, mark Feb. 4 off the Continental Ledge in the Atlantic, fulfilling Jules Verne's 1870 fantasy about an undersea craft of nearly limitless range (NU, Feb. '57, R5). She has now logged 60,120 nautical miles [69,138 statute miles], 34,500 of them submerged; made 859 dives; cruised 5,400 hr or 225 days; saved consumption of 720,000 gallons of oil—90 railway tank cars—by burning 2.8 lb U^{235} instead. And the *Nautilus'* medical officer, Dr. John H. Bersole, reported that his 106 shipmates have been exposed to less radiation than most people at home—because the ocean acts as a shield to protect them from background cosmic ray radiation.

• **Seawolf** spent two weeks in drydock for "routine minor repairs," after having logged about 100 hr at sea. Chief of Naval Operations Adm. Arleigh A. Burke told Congress, "The ship is now operational but is being limited to 80% of its designed horsepower rating. This reduces its speed to about 90% of its design maximum. We will conduct further operational testing before making a decision in regard to this power plant." Later the Navy admitted that corrosion leaks were more extensive than previously disclosed, affecting steam generator as well as the superheater; and that "it is possible" her sodium-cooled reactor "may be abandoned" and replaced by a pressurized water type.

• **Submarine program.** For the 1958 shipbuilding program, the Navy is

asking Congress—in addition to the first nuclear carrier—for four nuclear subs, one attack-type and three guided - missile - launching. This would bring the total to 19. Meanwhile awards of four of the six nuclear subs authorized for the '57 building program were made, and two shipbuilders got their first nuclear ship construction contracts. Ingalls Shipbuilding of Pascagoula, Miss., will build SSN-590 and -592 for $41-million; Newport News Shipbuilding and Dry Dock Co. will build SSN-591 for $24-million. Electric Boat division of General Dynamics got its sixth A-sub job, SSN-589, to cost $25.8-million.

General Electric will build main turbines for five Westinghouse-powered *Skipjack*-type subs, SSN 588-592. Westinghouse will also build the carrier's main propulsion plant—turbines, condensers, etc.—for $8.1-million.

AEC Licensing News

Construction permits granted: Aerojet-General Nucleonics, for three AGN-201 low-power research reactors (serial 101, 102, 103), 2/22/57

Licenses granted: Aerojet-General Nucleonics, to operate AGN-201 (serial 101), 2/23/57; to transport and operate it at Nuclear Congress, Philadelphia, March 11–15, 2/26/57

Export license issued: AMF Atomics, to export a 1-Mw pool to Munich, West Germany, 2/26/57

Notice of proposed issuance of construction permit in 15 days: North Carolina State College, to modify solution-type research reactor for operation at 500 watts, 2/18/57

Lockheed Aviation, for critical facility at Palo Alto, Calif., 2/26/57

Application received: Loretz & Co., Los Angeles, to export a 500-watt Atomics International solution-type research reactor to Danish AEC, Cophenhagen, 1/17/57

Atomics International, to construct and operate 5-watt solution-type laboratory reactor at its Vanowen facility, Canoga Park, Calif., 1/24/57

Foster Wheeler Corp, to export 5-Mw tank-type research reactor to Danish AEC, Copenhagen, 1/25/57

Babcock & Wilcox, to construct and operate an addition to its existing critical facility at Lynchburg, Va., 2/1/57

Aerojet-General Nucleonics, for 12 AGN-201 research reactors (serial 109 through 120), 2/12/57

Union Carbide Nuclear Co., for 5-Mw AMF Atomics pool at Sterling Forest, Orange County, N. Y., 2/15/57

About the Industry

Unfilled orders for atomic equipment are up 213%, according to Westinghouse president Gwilym Price. The figure is for over-all atomic backlog, including Bettis as well as CAPA and Cheswick operations, on Nov. 30, 1956, as against Dec. 31, 1954. The firm is not making any money at present on its atomic power activities, he said, but "is playing for a position of leadership in the field when atomic power begins to pay off. . . . Westinghouse has built, or is building, more nuclear reactors designed specifically to produce power than all other companies in the U. S. combined—and to our knowledge, in the world."

Westinghouse also announced start of work on a new one-story addition to the main building of CAPA (commercial atomic power activities) in the Forest Hills suburb of Pittsburgh. The new wing, to be completed in six months, will include 12,000 ft² of laboratory space for nuclear power development work, including studies for the big homogeneous Pennsylvania Advanced Reactor.

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Clevite Corp. announces establishment of a nuclear materials group at its Cleveland research center. The firm disclosed it had already been doing nuclear materials research under contract for companies in the atomic field. Clevite's engine bearing business led it to do advanced work on high-temperature, highly corrosion-resistant materials, which in turn led to its work with uranium, zirconium, hafnium and niobium. Nuclear activities at Clevite have centered on developing efficient production techniques for reactor components, principally fuel elements and control rods. Equipment for the new center will include vacuum-arc and vacuum-induction melting furnaces; equipment for annealing, forging, precision-rolling and -machining and vacuum welding; and mechanical and chemical testing labs. The new program will be directed by Arthur D. Schwope, Clevite's materials division manager, who has long experience in metallurgical work done for AEC.

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Reactive Metals, Inc., a new company, has been formed by Mallory-Sharon Titanium Corp. and National Distillers Products Corp., to melt zirconium and Zr alloys, and to make Zr mill products. A plant will be built at Ashtabula, Ohio, where Distillers' U.S.I. Chemicals division is building a Zr sponge plant (NU, May '56, 21). Ownership of the new firm will be equally divided, but operation will be independent of the present activities of the two companies in the reactive metals field. Production later of other nuclear metals—Hf, Nb, Th—is contemplated. Distillers regards the new subsidiary as a complement to its sponge plant: pointing out that there are many steps between manufacture of sponge and fabrication of finished parts, and that capacity for all these steps must grow at the same rate to keep the sponge plant operating at full capacity when it comes on stream. Distillers explains the Reactive Metals plant will concentrate on making ingots and those mill products that cannot be supplied by others rapidly enough to meet the anticipated needs of industry.

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The new international combine of AMF Atomics and Mitchell Engineering of London has sold Germany's first private power reactor, a 15-Mw, $8–10-million pwr for RWE of Essen (NU, Oct. '56, R10).

LMFRE Design Shaping Up; To Go Critical in 1959

Babcock & Wilcox expects its Liquid Metal Fuel Reactor Experiment to go critical in 1959, its LMFRE technical manager reported to a local American Nuclear Society chapter meeting. Robert T. Schomer gave this date even though the project is still in pre-design stage. A reference design is now being developed for submittal to AEC in May, then detailed design will start. Present concept is of a reactor developing 20 Mw heat; steam will be made, but there are no plans for a turbine—unless a utility wishes to volunteer. Main problems: to find a containment material for uranium bismuthide; to prove out the use of unclad graphite, in contact with U-Bi, as moderator at high temperature; to develop necessary remote maintenance techniques. The unclad graphite moderator assembly will also serve as core tank; it will be sealed with graphite and the seams cemented and baked until impervious to U-Bi. Double containment will be necessary. Temperature drop across the reactor will be 135° F (750° in, 885° out). Later, economics can be improved by taking outlet temperature up to 975° F for a 225° F temperature drop. Fuel will be about 90% enrichment; 80 kg U^{235} in the entire system, less than 10 kg of it in the core. There will be no valves in the primary; gas pressure will be used to hold up flow, at 100 psi. A secondary circuit will use either Na or NaK, or fused salt. Steam will be at 800° F, 600 psi.

Brookhaven is doing preliminary work on using plutonium in an LMFRE system, Clark Williams reported.

EBWR: Good Prognosis for Boiling Reactor Economics

In the hot, Klieg-lighted atmosphere of a movie set, Joint Committee chairman Rep. Carl T. Durham —after half-a-dozen dry runs for press photographers—turned a handle-switch on a control panel of the Experimental Boiling Water Reactor at Argonne National Laboratory outside Chicago. It was 3:01 p.m., February 9, 1957. AEC chairman Lewis L. Strauss, standing at his side, pronounced EBWR to be on the line.

In that sense, the ceremony was symbolic, for EBWR had been on the line before since it first reached full power (20 Mw heat, 5 Mw electric) on Dec. 29, 1956—two days ahead of schedule. Actually the occasion marked only the beginning of the first extended full-power test run. What was significant was that EBWR, first of AEC's ten-approach development program completed, was the first reactor in the free world designed exclusively for power generation to enter service—and that EBWR, at the start of its life, is already a patriarch. For the reactor "family" of which it is the first had just grown to six commercial projects with the announcement of the Northern States Power group's entry (*see p. R9*); earlier boiling-reactor programs include Pacific Gas & Electric, Commonwealth Edison, Elk River, and two for American & Foreign Power.

At a festive press briefing the previous evening, EBWR's proud builders talked plans and prices. The reactor is now operating well on natural circulation of the coolant water; but more power could be extracted with forced circulation. So sometime this summer pumps will be installed in the 4 thimbles provided for the purpose in the vessel bottom, raising circulation from 7,000 to 10,000 gpm. Then, if the minimal leakage—amounting to a mere 2 lb/day—can be overcome. EBWR will get a coreful of heavy water next year, for even better performance. Radioactive steam has proved less of a problem than feared —the activity level is 5,000× less in the steam leaving the reactor than in the water in the core.

Excluding research and development costs and assuming 10-year core life to reach 1% burnup, cost of EBWR power is estimated at 30–35 mills/kwh. But even with natural circulation and light water, its builders believe it could operate at 40 Mw heat and 10 Mw electricity, twice the rated power level (only theoretically, for the generator's top capacity is 5 Mw)—and then cost comes to 20 mills/kwh as compared with 12–15 in an equivalent-sized conventional plant. Cost can be whittled further using forced circulation.

Capital cost of EBWR, "as she stands" and excluding research and development outlays, is $4-million, plus $1-million worth of fuel (fabrication and zircaloy cladding makes up a considerable part of the latter figure). To build a duplicate but with a 10-Mw generator would cost $4.5-million, plus core. EBWR's first core, at 1.4% enrichment, contains 132 lb U^{235}—about the size of a gallon can. Argonne is already working on fuel elements that would cost only 10% as much: Borax-4 has a ceramic core of thoria-urania clad in aluminum alloy; it produces 2 Mw electricity, and cost $75,000. If it works well in Borax, Argonne would feel justified in reloading EBWR.

AEC officials present declared the economic projections for this plant are as favorable, taking account of size, as for any reactor in the world today, or more so.

Geneva Reactor's Permanent Installation Nears Completion

After some delays, the U. S.-built Geneva exhibit reactor's new swimming-pool home is nearly ready (NU, July '56, R11). The building housing it was completed in August; the pool is of course a much larger one, divisible into two independent compartments. With the reactor suspended on an overhead traveling crane, it will be possible to prepare one shielding experiment in one half while still working on the preceding one in the other. Six horizontal irradiation channels will supply neutron beams for physics research. Calculations have shown that the thermal power may be taken above 1-Mw if forced cooling is provided. Pumps and heat exchangers are being installed, with cooling water to be taken from and returned to the River Aare, on the bank of which the Würenlingen research center is located. Availability of the beefed-up U. S. unit to Switzerland will make it possible to carry out research work two years earlier than originally foreseen when only the all-Swiss "P-34" heavy water research reactor was planned (NU, June '56, 19B).

P-34's buildings, started last May, are not yet completed. They include the reactor building with access tunnels for fuel handling; a boiler building, a general research lab, an isotope research lab, and an irradiated fuel processing lab.

Problems still awaiting solutions—expected to take two years—are: electric regulation and control systems; charging and discharging system for fuel elements in the core; various details of heavy water circulation.

P-34 will permit irradiation testing under varying pressures and temperatures.

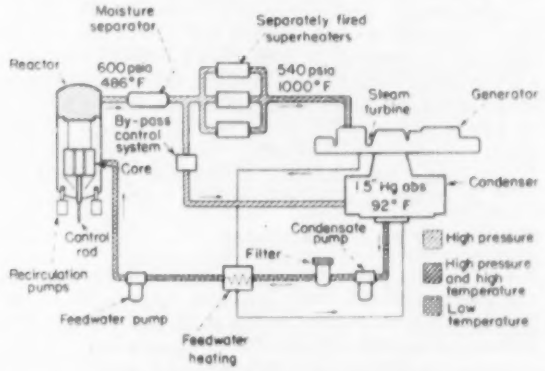
Reactor News

NORTHERN STATES GROUP TO BUY . . .

A group of ten utilities in the North-Central states headed by Northern States Power Co. of Minneapolis have banded together to get a 60-Mw Allis-Chalmers boiling reactor for $20–$25-million, to be completed by 1962. It will be located on a site yet to be chosen on the system of Northern States Power, which will own and operate the plant; interconnections between companies will permit power produced in the reactor to be distributed to the systems of the participating companies. Allis-Chalmers is prime contractor; Pioneer Service & Engineering Co., Milwaukee, will be architect-engineer. The utilities have formed a nonprofit corporation to finance jointly the research and development work required on the project. They are: Northern States Power; Mississippi Valley Public Service Co., Winona, and Otter Tail Power Co., Fergus Falls, Minn.; Iowa Power & Light Co., Des Moines, Iowa Southern Utilities Co., Centerville, and Interstate Power Co., Dubuque, Iowa; Wisconsin Public Service Corp., Milwaukee; Northwestern Public Service Co., Huron, S. D.; St. Joseph Light & Power Co., St. Joseph, Mo.; and Central Electric & Gas Co., Lincoln, Neb. Other utilities may decide to join later.

. . . NEW ALLIS-CHALMERS BOILING REACTOR

The reactor chosen by the Northern States Power group is described as an advanced type of boiling water reactor, a logical progression in development of this family of reactors, and one whose design may make a significant contribution toward economic nuclear power. Allis-Chalmers—which has been working on this design for



some time while building all the power generation equipment for EBWR—calls it a controlled recirculation boiling reactor. It features high energy output per unit of volume, achieved by recirculating a large volume of water continuously through the reactor (the 5 × 5 ft cylindrical core will generate as much heat, 133 Mw, as a boiler burning 20 tons/hr of coal). Reactor power will be adjusted by controlling the rate of water recirculation through the core, by means of large pumps at the bottom of the reactor. The water will carry along the steam produced in the reactor vessel, and steam bubbles will be separated by centrifugal devices; steam exhausted from the turbine is condensed and recirculated. If greater steam output from the reactor is desired, the speed of the recirculation pumps will be increased by automatic control, forcing out additional steam and raising the power level. When power demand drops, the pumps slow down, reducing the quantity of steam removed from the core and slowing down the reaction rate. The reactor will operate at 600 psia, delivering saturated steam at 486° F; a bank of conventionally-fired superheaters will raise steam temperature to 1,000° F at 540 psia at the turbine throttle. Steam flow will be 502,000 lb/hr. The reactor vessel will be 9 ft dia × 23 ft high, housed in a steel-and-concrete building 45 ft dia × 70 ft. The 100-Mw turbine-generator set, which Allis-Chalmers will also build, will be similar to that of EBWR, sealing in the slightly radioactive steam flowing through the turbine by special seals on the shaft. It will be housed in a conventional building.

BOILING WATER REACTOR FOR CUBA

A General Electric single-cycle 10.5-Mw boiling water reactor will be in operation in Cuba in 1959, American & Foreign Power disclosed at the first Cuban forum on civilian atomic energy. (A&FP had previously announced purchase of two GE boiling reactors and one Atomics International organic-moderated unit, and had said they would probably be installed in Cuba, Brazil and Mexico, but had not matched reactor types with countries. The remaining matching has not yet been decided.) The Cuban reactor will produce 600 psi, 490° F steam at the throttle. Fuel elements will be guaranteed to operate 15 months at 80% load factor.

TURNER TO ERECT IRL REACTOR FOR AMF

AMF Atomics has chosen Turner Construction Co. as builder of the Industrial Reactor Laboratories nuclear research facility at Plainsboro, N. J. (NU, Oct. '56, R5). The work will include a one-story reinforced concrete administrative and experimental lab building 168 × 188 ft; a dome-shaped reinforced concrete reactor building 90 ft dia × 85 ft high; a connecting tunnel with radiation-monitoring checks for personnel; a utility building; cooling towers, and other general site work. A construction permit has been issued AMF Atomics for the 5-Mw pool it will supply; work is to start shortly, and the entire job is to be completed by July 1, 1958. Skidmore, Owings & Merrill are the architects, Severud-Elstad-Krueger the structural engineers, Guy B. Panero the mechanical engineers.

SHORT LEAD TIME FOR BERLIN REACTOR

The 50-kw uranyl sulfate solution water boiler Atomics International (NAA) is building for the Institute of Nuclear Research of West Berlin (NU, Aug. '56, R11; Oct., R10; Nov., R1) is to be delivered within nine months, according to advices from NUCLEONICS' bureau in Germany. AI has started work on similar units for Frankfurt U. and the Danish AEC.

ARGONAUT ENTERS SERVICE

Argonne's Argonaut training reactor (*see p. 62*) went critical for the first time Feb. 9. It has been operating satisfactorily, and was to be turned over to the International School of Nuclear Science and Engineering at Argonne early this month.

NORTH CAROLINA REACTOR TO BE REBUILT

North Carolina State's pioneer reactor, first started up in Sept. 1953 but shut down since June 1955 owing to core leaks, has gotten AEC approval to operate at 500 watts (original power 10,000 watts) with a new core tank. This is an interim arrangement to permit immediate operation for instruction purposes; the college intends to rebuild the reactor to make possible operation at 10 kw again, or more. Precautions are being incorporated in the new core to prevent chloride-ion corrosion, believed to be the source of the trouble.

World News

Second Harwell for Winfrith Heath

Local objections to establishment of an atomic energy research station at Winfrith Heath—between Dorchester and Wareham and 5 mi from the Dorset coast—have been overruled by Minister of Housing and Local Government Henry Brooke after a 4-day public inquiry. AEA had applied for approval to use a 688-acre site as a reactor development center, being short of room at Harwell (NU, April '56, 23; Dec., R11). Local landowners and nature-preservers had objected to the project, contending it would mar the remote, beautiful and unspoiled countryside; AEA urged that use of the site was essential in the national interest. The green light given AEA requires it to obtain approval of local planning authorities on all detailed plans, designs and structures, and to provide screens of trees.

Norway Plans Reactor Exports

Production of reactors and other equipment for industrial atomic energy plants is being planned in Norway: 43 leading industry, banking and shipping firms have been invited to participate in setting up a company, Noratom, to market Norwegian technical and industrial know-how in nuclear power development. Subscription to shares in the sales pool would be open to the public; share capital would be between $280,000 and $700,000. At the outset Noratom would concentrate on high-quality parts and plans for reactors, later would offer to construct and operate reactors. The Norwegian Institute for Atomic Energy (NIFA), the country's chief center for nuclear research and reactor development and, together with its Dutch counterpart, the operator of the Joint Establishment for Nuclear Energy Research (JENER), has agreed to carry out consultation assignments for Noratom. Norway has already received inquiries from abroad for atomic equipment, and it is believed there is a market for improved versions of the first JENER reactor, operating since 1951 at Kjeller near Oslo, and of the second, a process steam reactor JENER is now building at Halden south of Oslo.

British Nuclear Ship: a Yes, a No

It was made clear for the first time in the House of Commons that the Admiralty is working on nuclear propulsion for surface ships as well as for submarines. Thomas Galbraith, Civil Lord of the Admiralty, said encouraging progress had been made on feasibility studies of nuclear power for surface ships; detailed work on a prototype nuclear power installation on shore was "well advanced," and a similar plant was planned for trials in a submarine. Some orders for machinery have been placed. Vice Admiral Sir Frank Mason, Engineer-in-chief of the Fleet, said the advent of nuclear power to warships "is almost wholly an engineering problem." On the other hand, British shipbuilders and owners at a meeting in London failed to arrive at the expected decision to start at least one prototype tanker powered by a water-moderated reactor. They got no farther, in fact, than to discuss "procedure to be followed in stimulating further progress in the field."

Japanese Zr Firm Set Up

First company in Japan to devote itself exclusively to production of reactor materials, the Toyo Zirconium Co. has been set up with a capitalization of $560,000 invested jointly by Ishizuka Research Laboratory and Nippon Mining Co. The firm will produce metallic Zr, already has an order for 100 tons from the U. S. Commodity Credit Corp. (NU, May '56, 21). It plans to import 3,000–4,000 tons of ore from Australia in the next two years. It will not use the new Japanese process (NU, Oct. '56, R8), but standard American methods.

Two Isotope Centers for Japan

The Japan Atomic Energy Research Institute is rushing preparations for a $4.7-million isotope center to produce, import and distribute radioisotopes and to give training in their use. It will have a Van de Graaff, cyclotron, isotope and radiation labs. Tokyo's Metropolitan Government has drawn up the first program for peaceful use of atomic energy to be undertaken by a Japanese local autonomous body: a four-year program for radioisotope application in industry, it involves setting up a research center to develop isotope uses in agriculture, the food and textile industries. Tokyo will spend about $400,000 on this program in the next fiscal year.

Moscow Seeks Mexican Students

Moscow State University has offered scholarships to Mexican students of nuclear physics. Grants include tuition, books, medical expenses and in some cases transportation. Applicants were asked to contact the Soviet Embassy. A spokesman there, questioned, would say only, "Oh yes, we would like very much to have Mexican students at Moscow University."

South Africa Tells U Production Data

The Atomic Energy Board in Capetown has disclosed that uranium oxide production in South Africa in 1956 amounted to 4,440 tons, with output at an annual rate of 5,000 tons by year's end—20% of the world's output. The Union has not yet reached full production. Indicated ore is estimated at more than 1.1-billion tons with a U content of 370,000 tons. Earlier, for security reasons, South Africa had given no output figures, except in terms of money value (NU, Jan. '56, 15). Value of the country's "prescribed materials" (mostly U) exports was £34-million ($95.2-million) in the first 11 months of 1956 as against £29.9-($83.7-million) in all 1955.

First Reactor Parts Reach Brazil

A U. S cargo plane last month unloaded eight crates weighing some 3,500 lb at Congonhas Airport, São Paulo, Brazil. They contained the first parts of the Babcock & Wilcox 5-Mw pool, first reactor to be installed in Latin America. A second shipment, weighing 12,000 lb and including the thermal column, arrived by sea; and another 5,000-lb air shipment contained reactor floor penetration equipment. Construction of the building to house the reactor is well advanced. Fourteen nuclear courses are being started at São Paulo University to coincide with arrival of reactor parts so that a well-trained team may be ready to handle it; a selected group of students will aid in final assembly.

First German Fuel Elements Delivered

Degussa has completed the first fuel elements made from German raw material, delivered them to the reactor group planning design of the Karlsruhe (first all-German) research reactor (NU, Oct. '56, R10) for severe testing to determine their reactor qualities. Cylindrical uranium rods of extreme purity, they are clad in aluminum bonded by a process developed especially for this purpose to make high heat transfer rates possible and to increase safety in case of can failure.

Report from Britain:

'Irradiation Creep' Strikes at Calder; British Have Trouble with Fuel Elements

"A brilliant piece of research work," dramatically foretelling unexpected and adverse effects of irradiation on the creep strength, came too late to prevent bowing of Calder Hall's lower fuel elements. This was officially admitted by Sir Christopher Hinton at a London press conference convened to dispel reports that the Calder reactor was down to low outputs.

It was revealed that two burst fuel elements had caused two emergency shutdowns so far, but the AEA refused to disclose whether these were bottom fuel elements. According to an official spokesman, "The cause of the failure of two out of 10,000 fuel elements has no statistical significance: to give details would be misleading." According to reliable sources, it is quite probable that AEA itself does not know the actual cause of the failures at this time, due to radiation levels prohibiting detailed analysis. Significant was Sir Christopher's only comment that the "usual fault [at Windscale] is no more than a pinhole."

Cure for the bowing at Calder Hall is to strap the center of the lower elements so as to zero their deflection, thereby reducing the effective length of strut and peak magnesium skin stresses. Effect of irradiation on creep strength in the CEA commercial power reactors will be less, thanks paradoxically to higher fuel temperatures. Other features in the CEA fuel elements such as independently-supported elements, shorter strut lengths, design out the bowing condition.

First quantitative analysis of the effects of irradiation on creep strength became available only just before Calder became critical. The creep mechanism is now referred to as the Cottrell effect, for it was the work of A. H. Cottrell, deputy chief metallurgist at Harwell, that clearly indicated that the bowing rates designed for on a purely thermal creep basis would be considerably exceeded.

Gamble that Failed

Nevertheless there were no research reactors with the flux density needed to simulate the condition, and so the decision was taken to proceed with the commissioning and examine the fuel elements at an early date. Bottom elements were sampled just before the Calder Hall symposium and by that time, even while the praises of Calder were being sung, it was known that AEA metallurgists had had their worst fears confirmed, and were grappling for the cure.

Initial feelings approaching despondency in metallurgical circles can be understood when it is recalled that attempts to retain the geometrical stability of the fuel elements—designed as struts and not as Euler columns—were a major part of a metallurgical research program probably without parallel in Britain. Principal achievement was the attainment of fined-grained, randomly-oriented crystal structure. This structure completely frustrates the distortion mechanism in uranium which, owing to its anisotropic plastic properties, exhibits preferential growth along particular crystal axes under irradiation. On the structural side, the need to minimize eccentricity in the stacked fuel columns had been met in the erection of the reactor with verticality limits having no precedent in civil engineering practice.

The Cottrell Creep

By the Cottrell effect, an entirely separate creep rate develops under irradiation which decreases with temperature. This is superposed on the normal thermal creep rate. When plotted on a temperature basis, the thermal creep rate curve goes up, irradiation creep rate curve goes down as temperature increases, so that the ordinates pertaining to each sum to maximum at a particular temperature. It so happened at Calder Hall that the temperature of the lower and hence coolest fuel elements—about 200° C—lay near this temperature bracket. Consequently, not only did these elements experience the worst creep rates, but being at the bottom of the stack were subject to the maximum strut load. The effect of creep on the struts causes bowing, not barreling, and is more serious because at this temperature also, manganese has a low ductility, hence poor resistance to cracking; thermal loads become asymmetrical, aggravating the condition.

The Cottrell effect in no way alters the particular manner in which a specimen yields by creep to an applied stress—it simply accelerates it.

At 400° C the Cottrell effect in uranium zeroes; and although the mechanism is not completely understood, the reaction at these temperatures is thought to be analagous to annealing.

Recipe for Calder

Strapping of the bottom elements at the No. 2 Calder reactor, now in operation, has already been carried out; the same modification will be effected on the No. 1 reactor at its next shutdown. Some reports have it that bowing had proceeded to the point where the elements touch the graphite, but the only official statement concerning their condition was that of Sir Christopher who stated that the general condition of the rods was not impaired.

The bowing effects due to both forms of creep in the CEA sets will be reduced to insignificance by: diminished irradiation effects due to higher temperatures, shorter strut lengths, and independently supported elements. Even when they're not independently supported, the worst creep rates in any case will not occur on the lowest, hence most heavily loaded, elements.

Remedy by General Electric

Although only GEC is prepared to release information on its fuel elements, it is reliably believed that all designs incorporate independent supports for the fuel elements, and are probably shorter than Calder. GEC makes several important claims for its design. Its element is 1.15 in. dia., 24 in. long, weighs 17 lb and is unalloyed natural uranium. Each canned fuel element is individually supported and positioned by non-metallic spiders inside a relatively large bore graphite tube. These tubes thus take all the load off the fuel elements and position on each other by a cup-and-cone arrangement, in the channel itself by graphite lugs. Main gas flow is up the tube bore. About 6% passes up the annulus between tube and core channel which collects heat due to collision processes in the graphite.

Other features include (1) smooth external shape of graphite cylinder, reducing abrasions in main channel during charging and discharging; (2) reactions between the CO_2 coolant and graphite become confined largely to the replaceable sleeves, eliminating mass transfer effects; (3) fission product contamination from burst fuel elements is confined to graphite sleeves, thus preventing contamination of the main core channel which might possibly mask detection of subsequent fuel bursts.

News in Brief

Reactors for Pumps?

Pumps for reactors have been a common problem in the field. Now the California State Assembly has voted $2,500 for a feasibility study on using nuclear energy as power source for pumping water. The state is planning a $1.5-billion project to pump water from the Feather River in northern California over the Tehachapi mountains to southern California, through a system of lifts and tunnels. Since about five times more power will be needed to lift the water over the mountains than will be generated by project hydroelectric facilities, atomic power holds hope of reducing delivered water costs to southern California users.

Buffalo U. Plans Early Start

Buffalo U. hopes to break ground for its $1.5-million nuclear research center this spring, is now preparing reports needed to get a construction permit. Houdaille Industries Inc. of Buffalo has just added a $50,000 pledge to earlier ones made by Bell Aircraft (NU, July '56, R12), the Buffalo *Courier-Express*, Hooker Electrochemical Co., Carborundum Co., and Columbus McKinnon Chain Corp.

Gibbs & Hill to Engineer Synchrotron

Princeton U. has retained Gibbs & Hill as architect-engineer for the $6-million, 3-Bev synchroton to be built at the James Forrestal Research Center. The machine, to be financed largely by AEC and used under joint administration of Princeton and Pennsylvania U., will produce heavy mesons in much larger quantities than has heretofore been possible. About the same size and energy as the 3-Bev Cosmotron at Brookhaven, it will have a much greater beam intensity, producing 50 times the proton current now available. The machine is now reaching the final planning stage after two years of basic design work.

New Armour Reactor Section

A new section for reactor and nuclear systems research has been set up within the physics research department at Armour Research Foundation. Its research field will include reactor concepts, core configurations, reactor kinetics, shielding, radiation processing concepts and irradiation-facility design.

Expansion at SRI

Stanford Research Institute is expanding its radiation research facilities, has obtained a 1-Mev General Electric electron-beam generator to study radiation effects on plastics and other materials, instruments, equipment, and food; polymerization; and initiation of chain reactions of various chemicals.

U. S., U. K. Exchanging Fusion Info

Exchange of classified and unclassified information on controlled thermonuclear reactions has been agreed on between Britain and the U. S. under the terms of the bilateral. Already a Harwell party has visited the U. S. last October to see and discuss work in this field; an American group made a return visit in November to Harwell and the labs of Associated Electrical Industries Ltd. which is doing contract work for the Atomic Energy Authority on fusion power; and a British group participated in a classified fusion conference held by AEC at Berkeley late last month.

Government Contract-Award Items

Grand Iron Works of New York has been awarded a $280,800 Corps of Engineers contract to fabricate, furnish and deliver structural steel for the Connecticut Aircraft Nuclear Engine Lab at Middletown, Conn. . . . Sperry Gyroscope Co. is being paid $25,202 by the Navy to conduct computer studies and analyses of new-construction submarines to provide a concise guide to crews on depth changing capabilities and limitations of these submarines. . . . A $32,939 job for a metallurgy radiation test facility for the Naval Research Lab in Washington has gone to Tri-Con, Inc., of Bethesda, Md. . . . Arrington Construction Co. of Idaho Falls, with a $1,119,280 bid, won the contract to build a low-power testing facility at the aircraft nuclear propulsion project at NRTS. . . . $469,100 will be the cost of a hot-cell area to be built, also at the Idaho ANP area, by J. H. Wise & Son.

AEC Contracts Extended

AEC's contract with E. I. duPont de Nemours for operation of the Savannah River plant has been extended until June 30, 1960; that with Goodyear Atomic Corp. for operation of the Portsmouth diffusion plant until June 30, 1961.

Radioactive Ink Developed

A new method of reproduction called electron printing, using low-energy radioisotopes mixed with ink, was patented last month by three LSU faculty members. A drawing made with the ink is exposed to a sensitized surface; no negative is needed. The number of copies is limited only by the life of the isotope, and the copy is said to have greater fidelity and subtlety than has been possible with photography.

Fuel Elements Flown to Holland

First shipment of privately-made fuel elements for use abroad was flown to Amsterdam. The seven Babcock & Wilcox elements, fabricated in three weeks, will be used in the AMF Atomics-built research and exhibit reactor; 22 more standard 20% elements and two experimental assemblies will be shipped this month.

AEC to Teach Atomic Firefighting

A three-day training course for instructors on control of fires involving nuclear materials will be offered by AEC at city and state fire-department schools requesting it. The Federal government will make no charge.

Reactor Test Device Installed

The Naval Magazine at Port Chicago, Calif. (near the Mare Island naval shipyard) dedicated a 2-million-volt GE X-ray machine to test reactor castings for nuclear-propelled Navy vessels.

Southern Regional Council Constituted

Representatives of 16 Southern states meeting in Atlanta have formally set up the Regional Advisory Council for Nuclear Energy (NU, Sept. '56, R8). Aims are to study the value of a permanent interstate compact for nuclear cooperation, and to work out a pattern to develop, finance and build one or more major nuclear research and development centers for Southern industry in general. Initial budget is $80,000—$5,000 per state.

Dworshak Joins Joint Committee

Sen. Henry C. Dworshak (Rep., Idaho) has been named to the JCAE seat vacated by former Senator Millikin.

Another first from *RCL*

ALL-GLASS HALOGEN QUENCHED GEIGER COUNTERS

★ At organic counter prices

★ Non-photosensitive

★ Higher output pulse

a) Model 22H: Civil Defense Counter
b) Model 20H: Thin Wall Counter for Survey Meters
c) Model 71H: Thin Wall Jacketed Counter
d) Model 11H: General Purpose Thin Wall Counter
e) Model 11-7H: Long Thin Wall Counter
f) Model 5HH: Mica Window Counter

Halogen quench Geiger counters* of all-glass construction are now available from RCL. Outstanding features are lower cost, infinite life, larger output pulse, lower plateau slope, non-photosensitivity, and they are not affected by discharge.

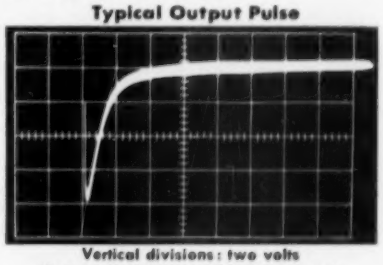
The quenching action of a counter containing halogen was first reported by Liebson. RCL is the first company to offer the all-glass halogen counter. RCL's halogen counters have been tested by experienced scientists and are stated to be the finest halogen quenched counters currently available. The tubes have a measured gas counting efficiency 20 per cent higher than other halogen counters.

RCL's halogen counters are available in a number of models, selection shown above. These are the most popular sizes based on RCL's over-a-decade of experience as the leading manufacturer of radiation counters; tubes.

The cathode surface is a patented, non-metallic conductive coating which is transparent. The thin wall section has the obvious advantage of a high transmission for beta radiation. The tubes can be used in open daylight with no spurious counts added because of the tube's non-photosensitivity. Operating efficiency is not impaired by extreme temperatures; there is less than 1 per cent change in counting rate when operated from minus 55°C to 110°C.

**First reported on by Clark.*

Typical Output Pulse



Vertical divisions: two volts
Horizontal divisions: 100 microseconds

Radiation Counter Laboratories, Inc.

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Nucleonic Park, Skokie, Illinois
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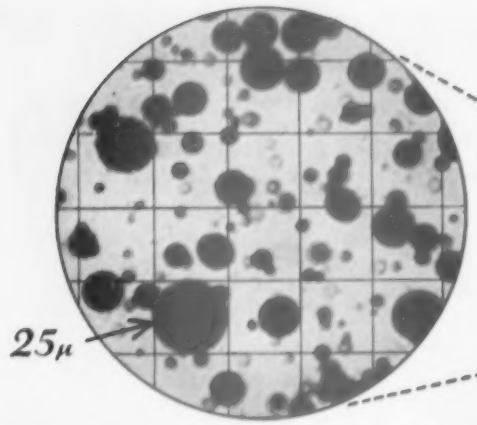

Here's the *latest* on Lithium METAL DISPERSIONS

Microscope and Illuminator by American Optical Company, Instrument Division, Buffalo, New York. Polaroid® Land Camera by Polaroid Corporation, Cambridge, Massachusetts.

Got a catalyst problem?

Interest sparked by the discovery that lithium metal dispersions make unique polymerization catalysts (the polymerization of isoprene to a "natural" rubber) indicates a heretofore unexploited instrument of research.

Consequently, Lithium Corporation is now making available experimental quantities of dispersions of this highly reactive metal. These dispersions may be purchased in either mineral oil or a mineral oil-petrolatum combination as the dispersing medium. Dispersions in other media are available as special items. The "package" is obtainable in five sizes from 25 grams to 1 pound. Over 90% of the lithium metal particles have a diameter less than 25 microns.

Specifications, information for preparing the dispersions including handling instructions, prices and product data on lithium metal may be obtained by submitting a request on company or institutional stationery.

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ATOMS AT WORK FOR PEACE

acf supplies Three Major Facilities for Europe

Making important contributions to Europe's growing Atoms-for-Peace programs, ACF Industries, Incorporated, is supplying major reactors to The Netherlands, Sweden and Italy. Both light and heavy water facilities are now under design and construction.

ACF is engineering and constructing a 20,000 kw light water research and materials testing reactor for the Reactor Centrum Nederland, a 30,000 kw light water facility for the Atomic Energy Company of Sweden and a 5,000 kw heavy water facility for the Italian National Committee for Nuclear Research.

The Nuclear Energy Products Division of ACF is active in designing and constructing complete reactor facilities for power, research, materials testing and other purposes. Inquiries relating to design and manufacture of reactors, components and allied equipment are cordially invited.

Engineers and scientists interested in joining this large, well-staffed and well-supported group are invited to inquire into the many available opportunities.

(left to right, seated): J. Pelser, Reactor Centrum Nederland; R. Vestergaard, Atomic Energy Company of Sweden; H. Etherington, Vice President, Nuclear Energy Products Division of ACF and former Director of Argonne National Laboratory's Reactor Engineering Division; Dr. G. Franco, (CISE) for the Italian National Committee for Nuclear Research; (standing): G. Anderson, ACF Manager of Reactor Engineering; J. J. Dickson, ACF Assistant Manager of Reactor Engineering; R. M. Jones, ACF Manager of Marketing and Planning; B. Swenson and B. Nelsson, Atomic Energy Company of Sweden; H. Henkel, ACF Project Engineer.

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nuclear energy products division

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AND HERE'S WHAT THEY

Visitors at the 1956 Trade Fair of the Atomic Industry were asked:—aside from the Forum Memo *"What technical and trade publications do you read regularly?"*

188 responses from representative industrial registrants mentioned 64 magazines—proving that the nuclear field reaches out horizontally to practically all branches of science and industry technology.

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*(NUCLEONICS had more than 22% of total mentions; **electronics** was second choice with a little over 5%.)

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31.4% — Forum mail promotions
24.8% — Exhibitor mail promotion to customers, prospects
13.3% — Word of mouth
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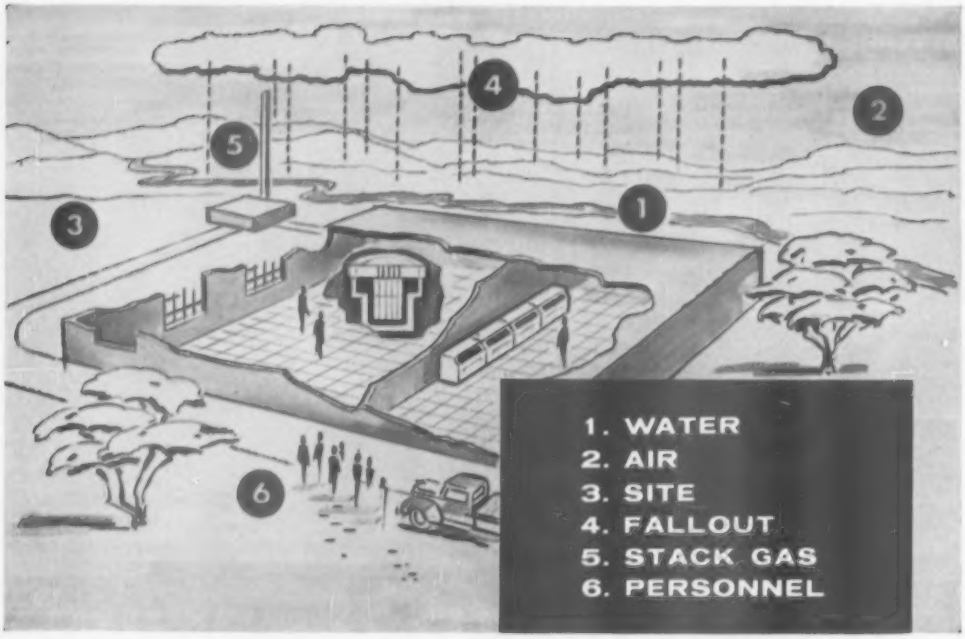

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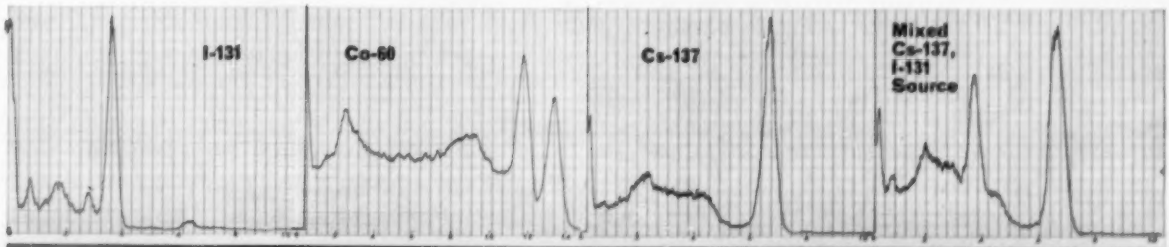
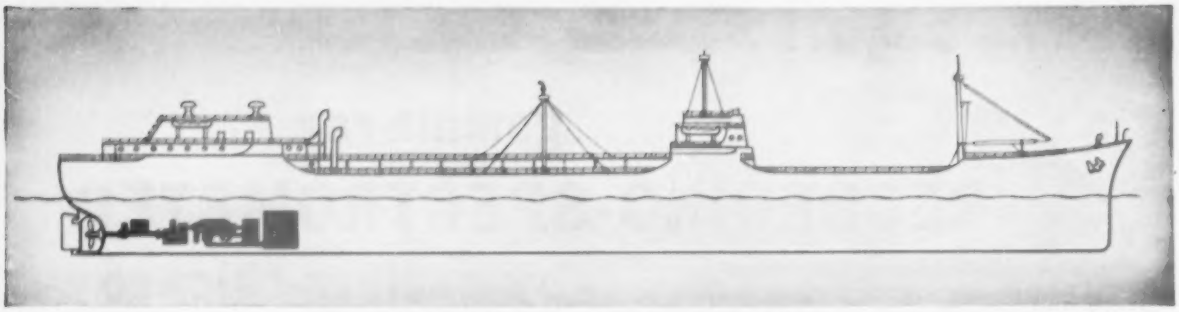


Typical scans made with Model 1820 Recording Spectrometer using DS5-3P scintillation detector with 2" x 2" solid crystal. Window width was ¼ volt during all four scans. Energy figures are in mev.



A CCGCR propulsion system as it would appear in a tanker.

PROGRESS REPORT NO. 2

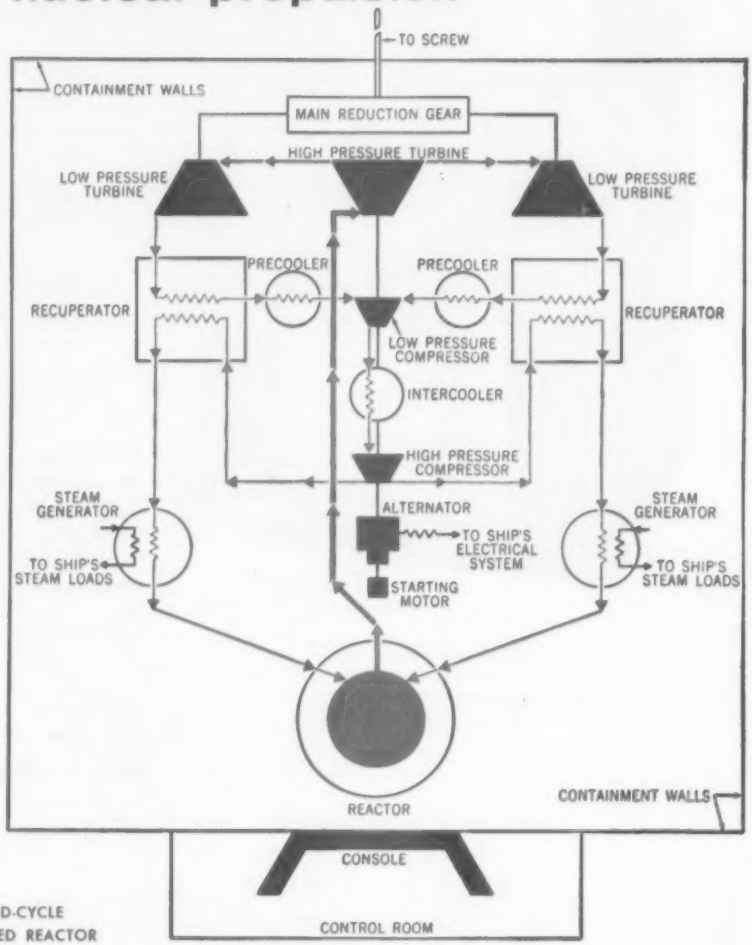
THE CLOSED-CYCLE GAS-COOLED REACTOR
...for nuclear propulsion

Ford Instrument Company is continuing its investigations of the Closed-Cycle Gas-Cooled Reactor, "The Eighth Reactor Type." Latest findings show that the CCGCR has many attractive possibilities for ship propulsion as well as for stationary power plants.

Illustrated on the right is a schematic of a ship propulsion system as visualized by FICo.

There are definite advantages which will make this plant attractive to ship operators. Among these is the drastic reduction of fuel storage facilities. This reduction in fuel carrying requirement can be reflected in additional revenue carrying capacity. In addition, such a system should offer:

- **Low Cost**
- **High Thermal Efficiency**
- **Maximum Safety**
- **A Minimum of Moving Parts**



Simplified Flow Diagram showing major components of ship propulsion system.

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REACTOR CONTROL COMPONENTS

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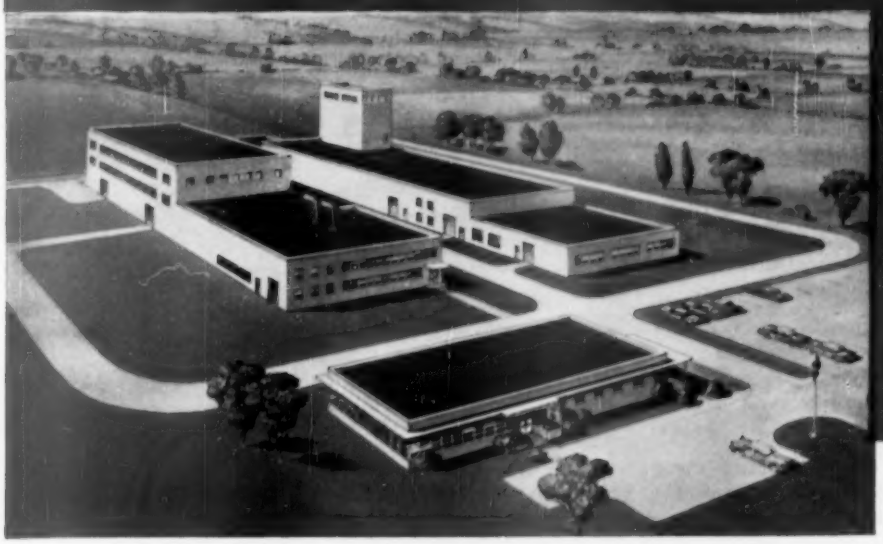
MORE ZIRCONIUM on the way ...from CARBORUNDUM METALS



NEW PLANT at Parkersburg, W. Virginia.

Construction has already begun on this new multi-million dollar Zirconium plant. The new production will provide more Zirconium for the open market.

THE METAL OF TOMORROW...TODAY

Zirconium production will soon be almost quadrupled by Carborundum Metals, currently the leading supplier of low hafnium metal for the AEC. Time-tested processing facilities at Akron, N.Y. are now being expanded and a new plant is now under construction at Parkersburg, West Virginia.

This means that *more* on-specification reactor and commercial grade sponge and ingot, ready for forging, rolling and fabricating, will be available — available by the middle of 1957 from the Zirconium industry's pioneer, leader and only experienced, large-scale commercial producer. For further information call or write to —

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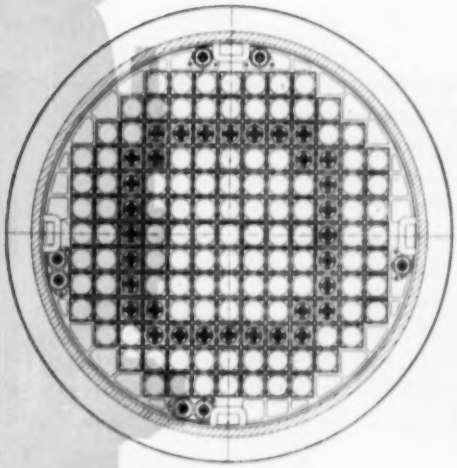

This pressurized water reactor vessel and its nuclear core were developed for the atomic power station at Shippingport, Pennsylvania, the nation's first commercial atomic power plant. With the success of the USS *Nautilus*, Westinghouse scientists and engineers continue to design reactor projects for other types of submarines as well as surface ships.

We welcome inquiries from physicists, mathematicians, and engineers interested in a challenging career in this expanding industry. Please address your resume to:
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One side	3 cm water
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Graduated from M. I. T., B. S. in E. E. 1949, and joined Bell immediately as Test Engineer on Rocket Instrumentation. A year later he was appointed engineer in charge of the Instrumentation Laboratory and in 1953, became Group Engineer of Standards and Calibration. After two years from 1954 to 1956 as a Test Engineer in the Army, he returned to Bell as a Group Engineer, a position he now holds in the new Research Division.

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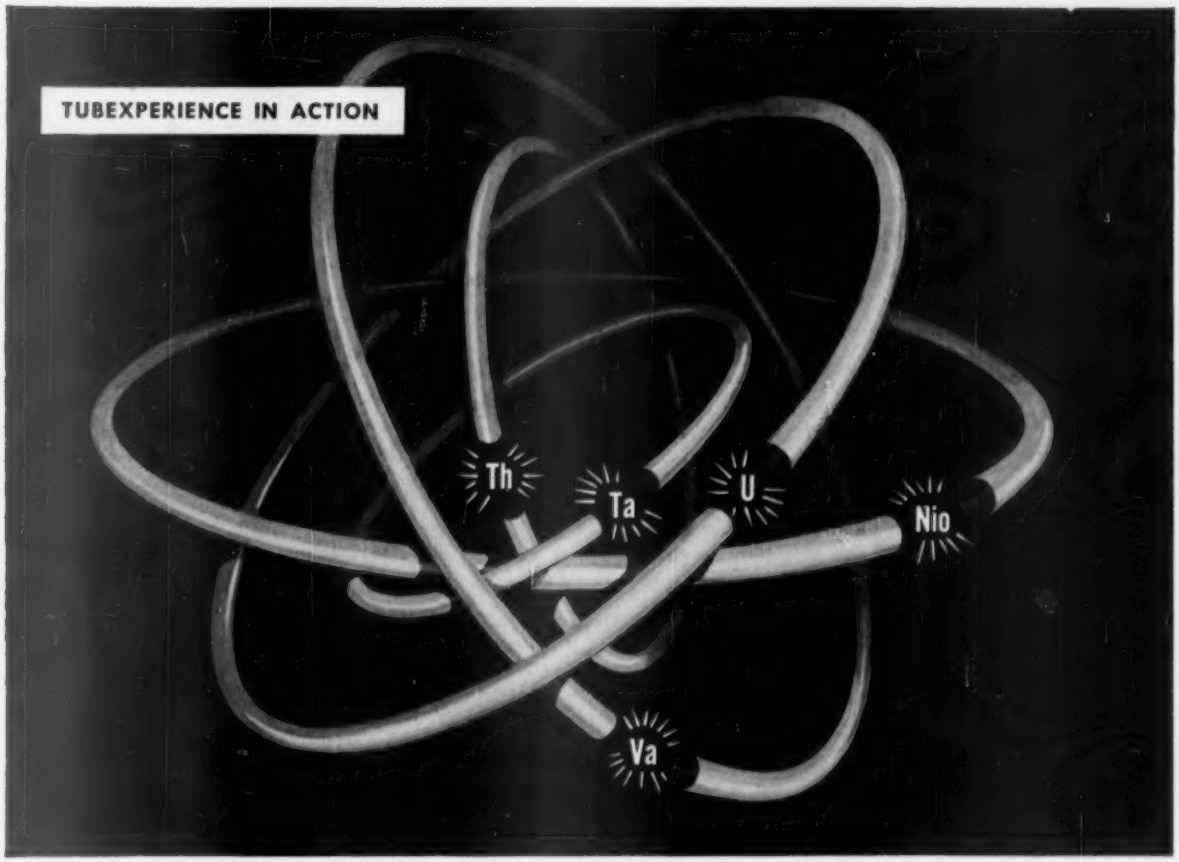

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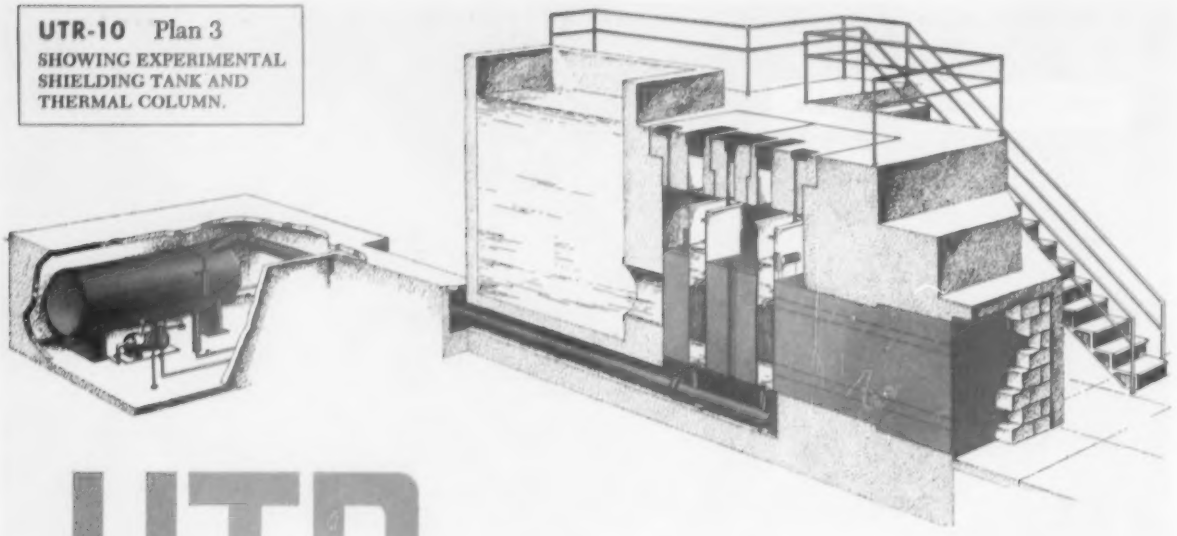

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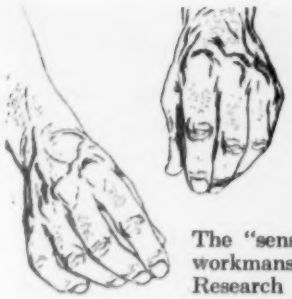

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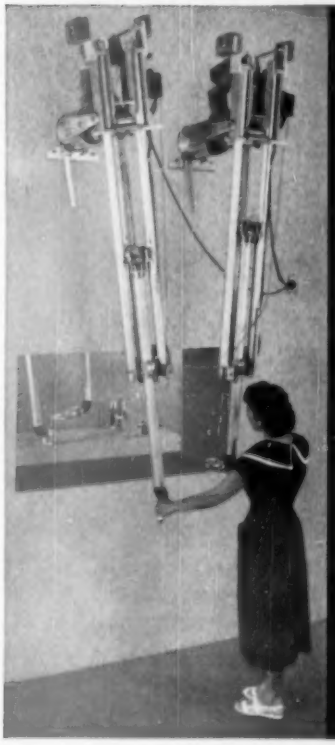
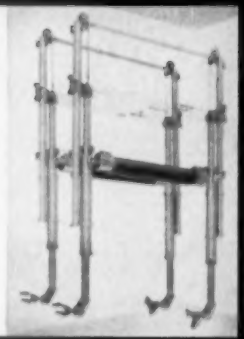
The "sense of feel", the versatility, the uncompromising workmanship . . . all are found in every CRL Manipulator. Research and production organizations all over the world are using these units for handling radioactive materials, explosives, and hazardous chemical and biological materials. Natural motions of the operator's hands are copied exactly at the slave end. The "sense of feel" helps the new operator to become perfectly competent with practically no training period. Handles are adjustable to comfortably fit a wide range of hand sizes.



CRL Model 4

for over-wall installation

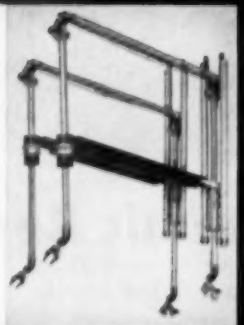
A general purpose manipulator for installation over a barrier wall or through a ceiling opening of a protective enclosure.



CRL Model 7

for restricted space installation

A space conserving, light weight manipulator for use in hoods or over thin walls where minimum clearances and easy portability are important factors.



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A general purpose manipulator for installations requiring intermediate to high level shielding, the Model 8 features

- *Accurate "sense of touch"* Low friction forces . . . low backlash . . . low inertia
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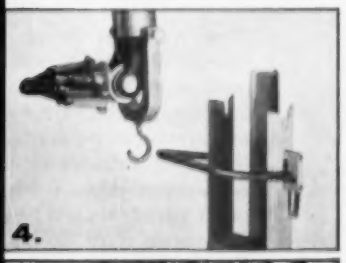
5. *Motion locks* Permit objects to be rigidly positioned in space. *Locking grip* standard on all models. Locks for all other motions available as accessories.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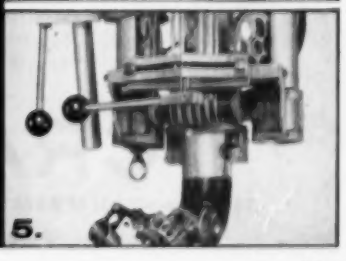
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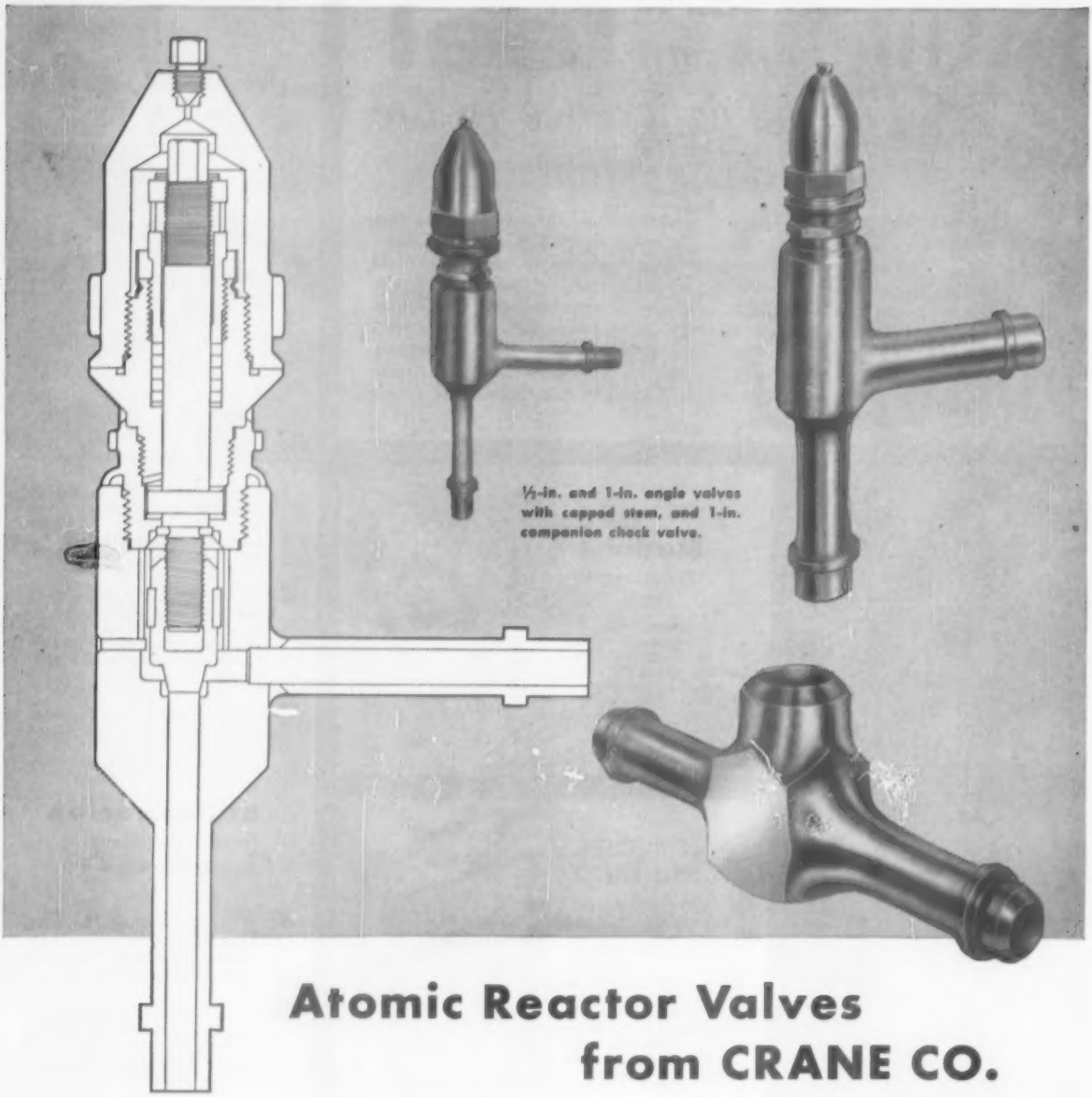

½-in. and 1-in. angle valves with capped stem, and 1-in. companion check valve.

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These angle valves are furnished in sizes ½ to 2 inches. Companion globe and check patterns are also available.

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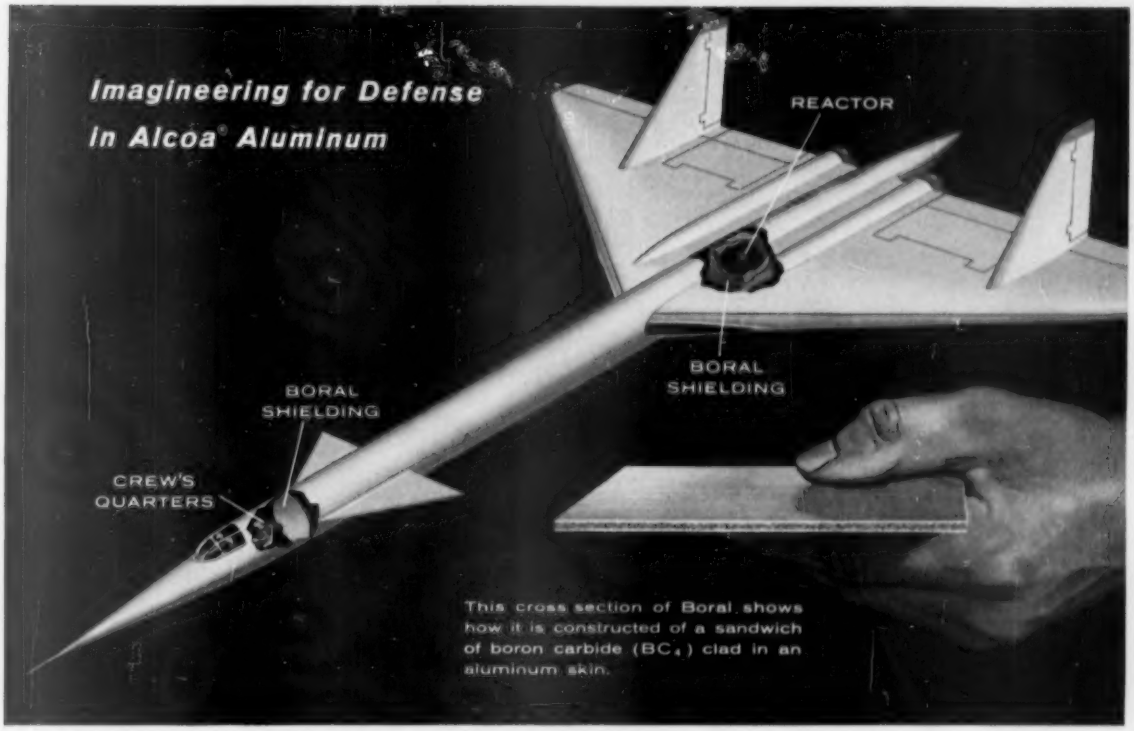
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This cross section of Boral shows how it is constructed of a sandwich of boron carbide (BC_4) clad in an aluminum skin.

New **Alcoa Boral** stops neutrons 100 times better than concrete

The high neutron density from the reactor represents a very real danger to the crew of an atom-powered plane. Since it is impossible to get very far away from the source of the radiation, effective shielding must be used to block neutrons. Yet shielding is either very bulky and heavy, as in the case of dense concrete, or heavy and expensive, as in the case of lead.

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In response to AEC's invitation to commercial producers, Alcoa has developed a fabricating procedure that provides Boral plate and sheet in the largest sizes ever offered. It is made in thicknesses of ⅛ in. and ¼ in.; sizes 48 in. x 120 in. and 36 in. x 96 in.; annealed or "as-fabricated" tempers.

While Boral is ideal for mobile reactors such as those used in the Nautilus or in aircraft, it can be used anywhere that space and weight limitations are critical. It is already in use or planned for atomic power and research reactors of many types. It makes possible far more compact and workable designs.

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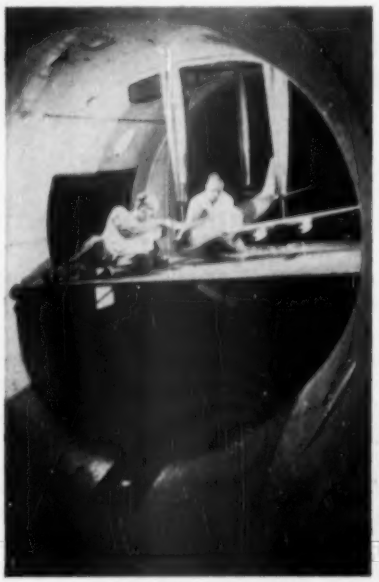

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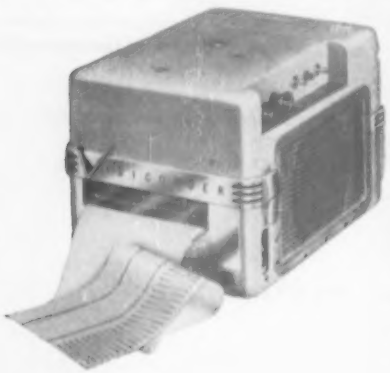

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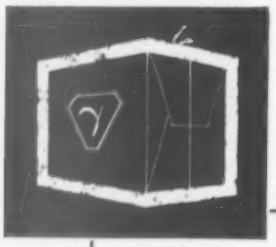

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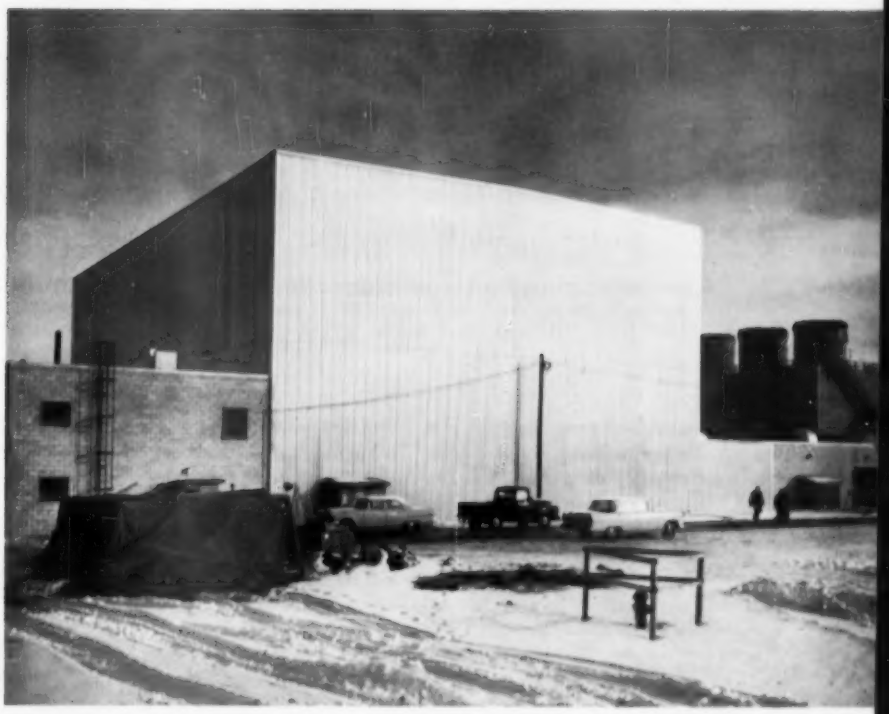


More Space for Radiation Tests

In May of this year the Engineering Test Reactor will go critical at the National Reactor Testing Station in Arco, Idaho. This will more than double the high-flux space available for tests of reactor components. Power and average fluxes are impressive: 175 Mw, 4 x 10^{14} thermal, 1.5 x 10^{15} fast. Facilities are provided to conduct tests under environmental conditions of temperature, pressure, and surrounding media that simulate those encountered in the end use.

In this special report the editors of **Nucleonics** present a detailed description of the ETR, its design, construction, and facilities set against the larger frame of the burgeoning need for test-reactor facilities.

The need for test-reactors will remain acute even after ETR has gone critical. ETR is intended primarily to serve the needs of the Atomic Energy Commission's civilian (power) and military (propulsion) reactor development program. It leaves unsatisfied needs arising in connection with private and foreign reactor programs, for in spite of the fact that ETR space can be allocated for such private needs, it is not expected that any substantial amount will be available. Thus still more test reactors are needed—we hope this report will help stimulate activity directed toward filling that need.

Test Reactors— The Larger View

Test-reactor requirements depend upon development demands, test-reactor capabilities depend on the state of design art. Compromising these considerations is the design challenge

THE ENGINEERING TEST REACTOR represents the very latest example of the test-reactor art, yet it is not the last word. As the nuclear field grows so will the complexity of test-facility requirements. It is useful therefore to trace the evolution of ETR's conceptual design as well as to look beyond today's needs to the test reactors of the future.

Lessons from MTR

The Materials Testing Reactor, first true test reactor, contributed invaluable operational experience for the design of the ETR. Some of the most pertinent lessons follow:

1. Fluxes below 5×10^{13} thermal neutrons/cm²/sec were not in demand. In the U. S. several other reactors could provide this flux. Hence, most of the graphite zone in the MTR was little used except as a "mine" for isotope production.

2. Beam holes for engineered experiments were very expensive and involved difficult design, construction and handling problems. Flux levels fall off rapidly so that sufficient space at uniform flux is not available.

3. Many experiments require more space in order to establish the proper environment—high pressure, high temperature—and still not have an effect on the MTR.

4. The vertical and horizontal flux distributions did not provide much space at uniform flux.

5. Important experiments, particularly those on fuel assemblies, preferred a pile flux rather than pure thermal flux.

As a consequence, the ETR is designed to provide large spaces at high fluxes right in the reactor core. The flux is reasonably uniform along its 36 in. of length. Closed loop-type auxiliary facilities for any desired coolant are provided in the original construction; and there is no secondary graphite reflector.

Future Test Reactors

Four types of tests are envisioned for the future: materials, components, core systems, and reactor prototypes. Three general types of test reactors appear adequate for the majority of the most important experiments: (1) thermal and/or fast advanced materials-testing reactors, (2) an integrated set of facilities, in each of which a single test can be conducted, and (3) ETR-type reactors that provide facilities for the transition between advanced materials tests and verification of whole reactors or large segments of them. The ideal characteristics for such test reactors are tabulated below.

A reactor with small holes and the highest possible thermal flux is the most important future need. Fluxes should be of the order of 10^{15}. Since gamma heating has given considerable trouble in MTR and ETR, the design should maximize the ratio of flux to power density. The reactor should operate at the highest temperature and pressure consistent with ease of operation and economy.

A multifacility swimming pool has been designed and proposed for the MTR-ETR complex. It would provide three types of facilities: (1) a large air-filled cavity fed by a uranium converter plate to provide a 10^{11} fission flux, (2) a water facility with a somewhat lower fission spectrum ($\sim 10^{9}$), and a tank to provide a normal reactor spectrum of leakage neutrons free of gammas. Graphite columns would feed neutrons to the converter plates. The reactor would operate at 1 Mw and require some cooling.

* Based on a speech by John R. Huffman, Atomic Energy Division, Phillips Petroleum Co., presented at the Power Reactor Conference in Belgium, November 26, 1956.

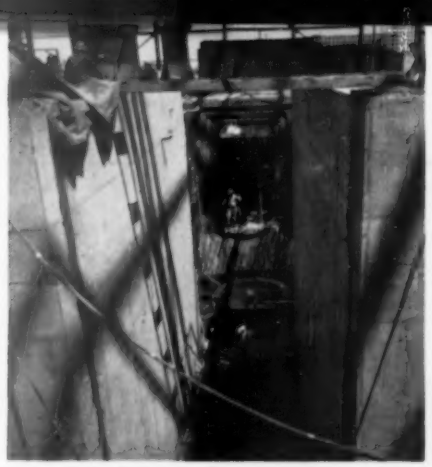
Ideal Conditions for Advanced Testing Reactors

Environmental conditions

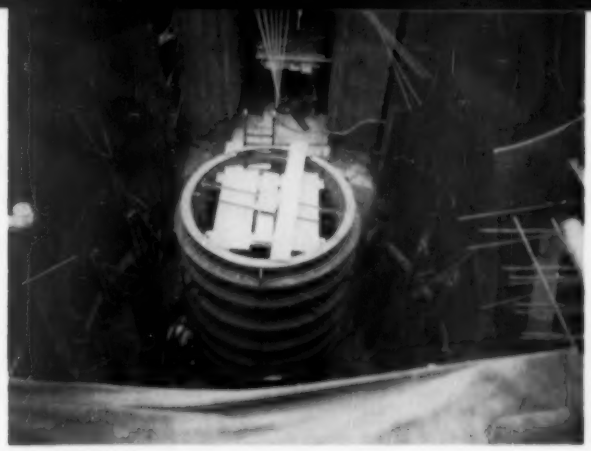
	Materials tests	*Single components*	*Core systems*	*Reactor prototypes*
Thermal flux	$0.5–1.0 \times 10^{13}$	$0.5–5 \times 10^{13}$	5×10^{14}	5×10^{14}
Fast flux (>0.1 Mev)	$>5 \times 10^{13}$	$0.5–5 \times 10^{13}$	5×10^{15}	5×10^{15}
Cross section of test volume (in.)	3×3	9×9	$>9 \times 9$	—
Length of flat flux (in.)	~12	24	24	24

Operating conditions

	Water	*Air*	*Liquid metal or salt*
Temperature (°F)	1,500	4,000	1,500
Pressure (psi)	6,000	300	

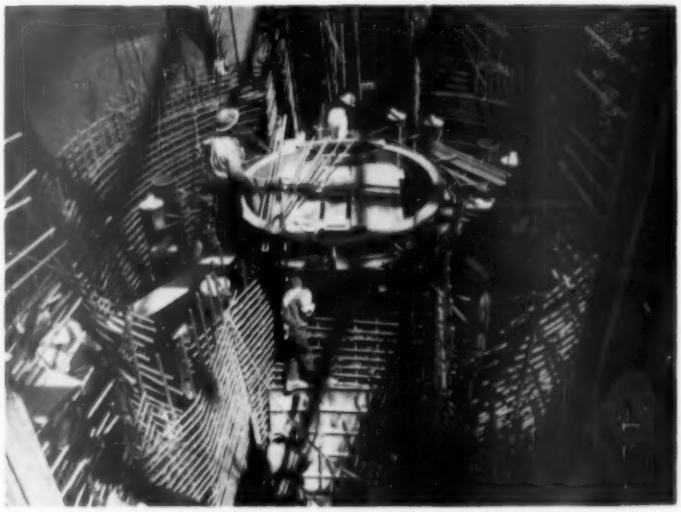


JUNE 5, 1956—View of reactor area. Channel between core position and camera is portion of disposal canal designed for handling spent fuel elements and radioactive equipment

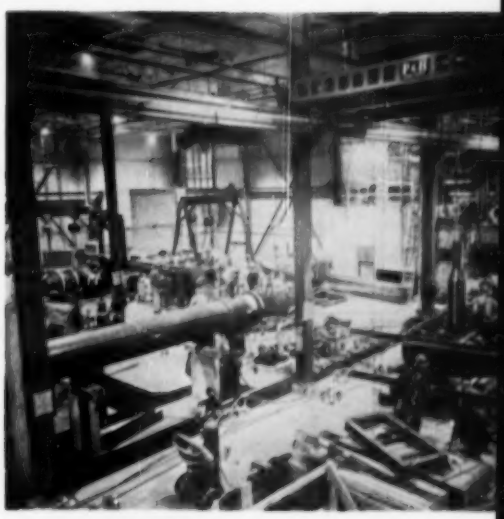


JUNE 20—External thermal shield as seen from first-floor level. Shield is one of five intended to reduce heating of cement biological shield from neutron and gamma radiation. Other four are inside pressure vessel

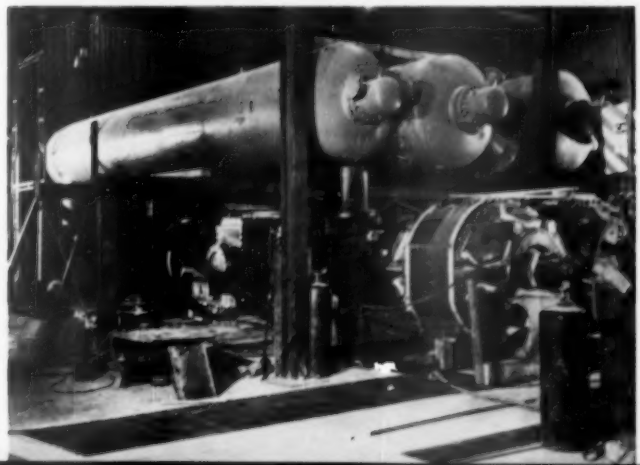
Building the etr



JULY 10—Reinforcing steel in place around thermal shield ready for third pouring of high-density concrete. Bed plate for supporting pressure vessel will rest on concrete at top of thermal shield



NOVEMBER, 1956—In compressor building workmen assemble 4,000-hp compressor drive motor (right). Experimental heat exchanger is in left foreground



DECEMBER, 1956—Air compressors that will supply surge tank lie on their rack and await installation

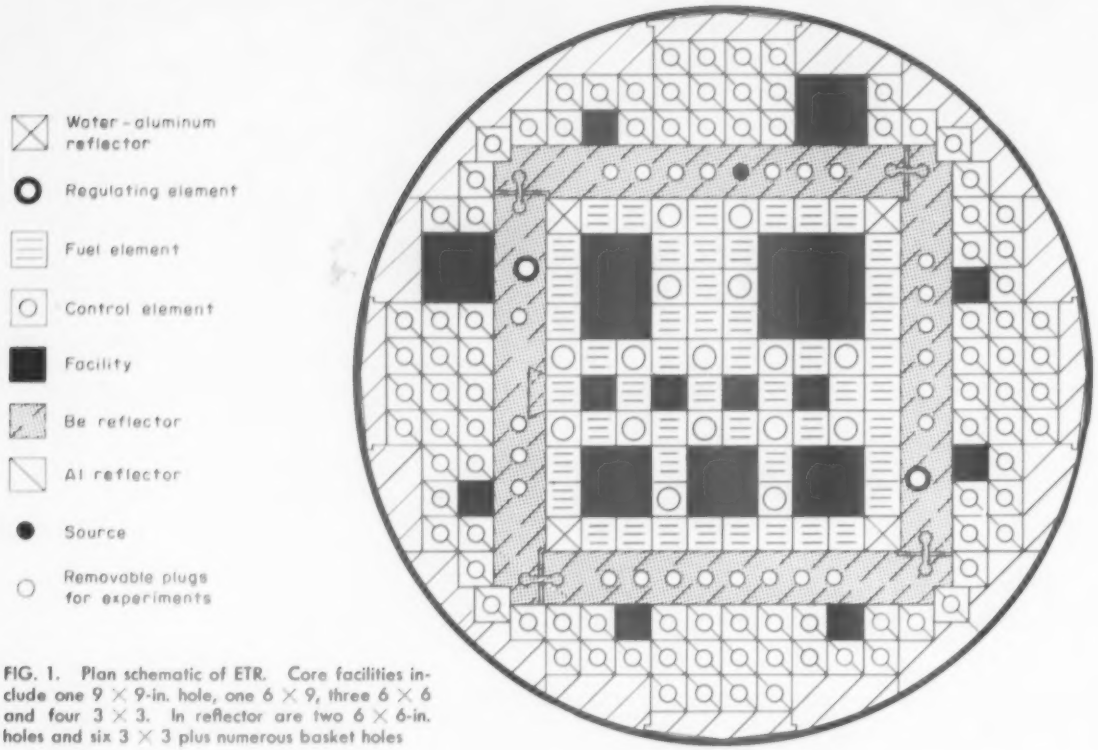


FIG. 1. Plan schematic of ETR. Core facilities include one 9 × 9-in. hole, one 6 × 9, three 6 × 6 and four 3 × 3. In reflector are two 6 × 6-in. holes and six 3 × 3 plus numerous basket holes

etr: Core and Facilities

The ETR core design features large test volumes with high-flux. Control system has black and gray bottom-driven rods. Boron is put in fuel cladding to minimize reactivity changes. It all adds up to a reactor with significant engineering usefulness

By R. H. DEMPSEY, J. J. JACOBSON, SALOMON LEVY, and BERTRAM WOLFE
Atomic Power Equipment Department, General Electric Company, San Jose, California

Characteristics of the Engineering Test Reactor

OVER-ALL

Power level	175 Mw
Power density of core	494 kw/liter
Core life before refueling	3,500 Mwd

CORE—excluding experiments

Average diameter	32 in.
Height	36 in.
Core volume	21,600 cu. in.
U^{235} content (initial core no experiments)	~14.1 kg startup; ~9.5 kg end of cycle
U^{235} content, with first set of experiments	~13.2 kg startup; ~9.0 kg end of cycle
Metal-to-water ratio	0.67
Thermal neutron flux, average over 3,500 Mwd	4×10^{14}
Epithermal flux, average over 3,500 Mwd	1.5×10^{13}
Poison content, initial core, no experiments	1.55 gm B per fuel element; 0.63 gm B per control-rod fuel section
Poison content, first set experiments	2.62 gm per fuel element; 1.07 gm per fuel section of control rod

FUEL

Fuel assemblies: (active plus inactive)	Rectangular, 3 × 3 × 55 in., 2S aluminum
Number of assemblies	49 (plus 16 in control rods with less leading)
Plates per fuel assembly	19
Fuel plates per control rod	14

CONTROL

Type of control rods	rectangular, upper section absorber, lower section fuel assembly (except regulating rod which has no fuel)
Number of control rods	
Black	4
Gray	12
Regulating	2
Rod worths	
Black, total of four	14.4% Δk/k
Gray, each	1% Δk/k
Regulating, each	0.4% Δk/k

COOLING

Inlet pressure (to vessel)	200 psia
Inlet temperature (coolant)	110° F
Outlet temperature (coolant)	138° F
Number of passes of coolant thru reactor	1
Coolant velocity in fuel passages	35 fps
Coolant flow	44,400 gpm
Heat transfer area	1,208 ft²
Average heat flux	440,000 BTU/hr/ft²
Maxium heat flux	1,150,000 BTU/hr/ft²
Hot-spot factor	2.5
Maximum fuel-element surface temperature	277° F

THE REACTOR CORE for the Engineering Test Reactor was designed to provide large experimental spaces with high uniform fluxes within the core itself. Experience with the Materials Testing Reactor and a 1954 study by the group at Phillips Petroleum Co's. Atomic Energy Division provided valuable background for the design finally evolved.

Calculations of criticality, flux distributions, and control effectiveness were checked by a short series of confirmatory critical experiments in the reactivity-measurements facility at the MTR site during the spring of 1956.

Core

The ETR has an asymmetrical core containing 49 3-in.-square fuel elements, 12 gray control rods, 4 black control rods, 2 regulating rods, and 17 experimental penetrations, as shown in Fig. 1 and the table. Cooling and moderating light water flows down through the fuel and beryllium reflector. Each control element has a fuel section in addition to the poison section. Average burnup for a 20-day operating cycle is about 33%.

In-Pile Facilities

The table summarizes the space available for experiments in the ETR core and reflector. Core facilities are surrounded on all four sides by fuel; reflector facilities are in the aluminum-reflector region adjacent to the beryllium. Active length of all facilities is 36 in. Holes are also provided in the beryllium reflector for the later addition of certain experimental facilities if desired.

Penetrations through the pressure-vessel wall and bottom head permit direct connection of coolant and pneumatic, hydraulic, or electrical power to the individual experiments without interfering with reactor operation. They also provide access for experimentation and operational instrumentation. In certain cases, they provide access to experiments for replacement of specimens or the entire experiment without having to remove the pressure-vessel head.

Two general classes of experiments are provided for—outside loops and inside loops. All core and reflector holes, except the two central 3 × 3-in. holes, can accommodate an outside loop.

Fuel Elements

The ETR fuel elements (Fig. 2) are flat-plate MTR-type aluminum-uranium assemblies. They have an active length of 36 in. and will contain, for theoretical loading without experiments, approximately 255 gm of U^{235} together with 1.55 gm of burnable poison (elemental boron). Each element has 19 0.050-in.-thick 2.626-in.-wide flat plates that are brazed into aluminum side plates so as to form a 3 × 3-in. assembly.

Each fuel plate consists of a homogeneous enriched-uranium-alloy core, 0.020 in. thick, completely clad with a

0.015-in. layer of 28 aluminum. The burnable poison is contained in the cladding. The cladding is bonded to the uranium core by a hot-rolling process to insure adequate contact between the two parts.

A cylindrical end connector welded to the fuel-element side plates seats and positions the fuel element in the core.

Reflector

A 4½-in.-thick beryllium reflector surrounds the core. It does the following: (a) flattens flux distribution in the core, and thus decreases the hot-spot ratio permitting running the reactor at a higher power level; (b) decreases the neutron leakage from the core and thus decreases the required fuel loading; (c) provides a buffer between the core and the experimental holes in the aluminum reflector, thus reducing the effect of high-cross-section experimental materials upon the core flux. In addition the two regulating rods are located in the beryllium reflector.

The reflector contains about 1,400 lb of type QMV beryllium, and consists of four sides 37.5 × 34.5 × 4.5 in. Aluminum reflector pieces, each 3 × 3 × 37.5 in., surround the beryllium. Any of the aluminum pieces can be removed to provide additional space for experimental facilities. Pressurized water flowing through the aluminum pieces serves to cool them.

Control System

The ETR control system allows operating control of the reactor by compensating for temperature coefficient of reactivity, transient xenon and samarium poisoning, burnup, and fission-product accumulation. Major changes in reactivity caused by experiment changes are compensated by changes in core loading. This is consistent with the type of experiment to be run in the ETR, in which various

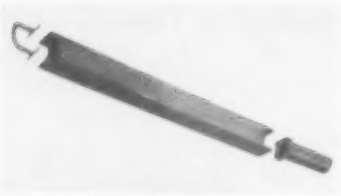


FIG. 2. Prototype of ETR fuel element. Handle (left) and adapter (right) are aluminum alloy

types of fuel elements will be irradiated in the experimental loops for long periods of time.

Mechanical actuation of control rods was selected so as to eliminate the development program required with newer types of low-distortion systems (such as soluble poisons in the coolant).

Burnable poison. Elemental boron was included in the fuel element to reduce the range of reactivity to be controlled by mechanical means. The neutron-absorption cross section of the poison is such that it burns out at nearly the correct rate to compensate for the burnup of the uranium. Perfect match is not obtained, but the burnable poison will reduce the change in reactivity due to burnup from 15% to 7%. This residual mismatch in compensation produces a reactivity that is fairly constant (or even rises for some experimental loadings) during the early stages of reactor life and falls during the latter stages. The trend with time of the major reactivity changes is shown in Figs. 3 and 4.

Control requirements. The control that must be obtained by mechanical means is about 3% for xenon, 1% for other fission products, 1% for temperature changes and 7% for poison mismatch, making a total of 12% not including any allowance for operational margin. Actually, the reactivity allowances for xenon and poison mismatch are not truly additive.

The ETR has only a minimum amount of xenon override. Either accidental shutdowns will be corrected in a very short time or the reactor will be refueled or will be left shut down until the xenon decays. The time available to restart after a shutdown will vary from about 26 min at the start of the cycle to zero time after about 17 days of operation (see Fig. 5).

Control rods. To provide the necessary control without seriously perturbing the flux, both gray and black control rods are used. Each of the twelve gray rods is composed of a gray poison section with a fuel section on the lower end. The gray poison's capture and scattering cross sections are nearly equivalent to those for a normal fuel element, but the poison section contains no fissionable material.

Thus, inserting a gray poison section distorts the flux only by removal of the source of fast neutrons from the area. Because the effective source of thermal neutrons is spread out, the flux depression produced by the rod is mild. These 12 rods provide the 12% operating control. They are distributed uniformly through the high-statistical-weight region of the core.

Four black rods composed of an upper black-poison section and a lower fuel section are used to ensure shutdown when required. During normal operation the black poison will not be in the core. The total effectiveness of the black rods is 14.4% in k for the four rods.

All 16 rods are used in the scram system so that a total decrease of 26% in reactivity can be inserted into the core in a very short time.

The control-rod assemblies consist of the poison and fuel sections above a shock-absorber section. The drive mechanisms are adaptations of the type used on the Oak Ridge Research Reactor (ORR), with a magnetically

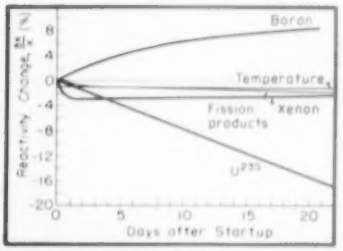


FIG. 3. Percentage change in reactivity from various sources with operation for startup core

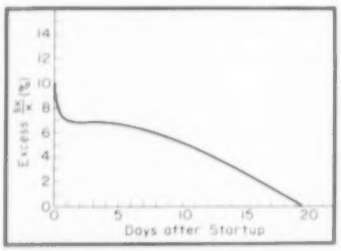


FIG. 4. Percentage excess reactivity, expressed in percent, as function of operating time

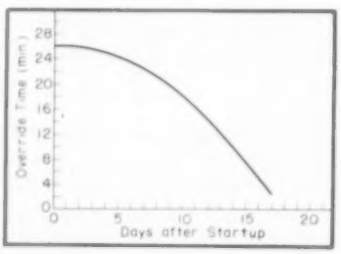


FIG. 5. Time available to override xenon after scram, assuming 4 min to get to full power after startup

actuated scram system. Bottom drive is used with gravity and differential pressure forcing the control element down during scram conditions.

Two regulating rods are provided which operate on an automatic flux high-speed servo system and compensate for small changes in reactivity. The rods are worth about 0.4% k each with only one being used at a time, the other being a spare.

Shutdowns

The control system can reduce reactivity quickly in six ways: fast electronic scram, full scram, junior scram, rundown, slow set-back, and fast set-back. These are illustrated in Figs. 6 and 7.

The fast electronic scram is initiated by high neutron flux, short reactor period, and loss of relay or instrument power. It electronically releases all black and gray control rods.

The full scram is initiated by experimental interlocks, loss of relay power, low water flow, abnormal differential temperature, or excessive power. It will release, by relay action, all black and gray rods.

The junior relay scram is initiated by experimental interlocks, high neutron flux, excessive power (water), high discharge-water temperature, and high inlet-water temperature. This scram releases a controlled number of gray and black rods, reducing the power level slowly enough so that the reactor can be brought back to normal operating conditions without going through the complete startup procedure.

Rundown is initiated by high neutron flux, short reactor period, high N^{16} activity, high water-inlet or -outlet temperature, low water pressure, low water flow, excessive power (water), or abnormal differential temperature or pressure. These conditions will cause gray control rods to run into the reactor, reducing power until the rundown is manually stopped by the operator.

Fast set-back is caused by abnormal experimental conditions and by excess thermopile-sensed flux. It can also be initiated manually. It will reduce the servo set point for the regulating rod by means of the high-speed log rheostat motor.

Slow set-back is initiated by high neutron flux, abnormal experimental conditions, high N^{16} activity, excess thermopile-sensed flux, low water pressure, low water flow, abnormal differential temperature or pressure, or excessive water power. It can also be initiated manually. Slow set-back reduces the servo setpoint for the regulating rod by means of the low-speed log rheostat motor.

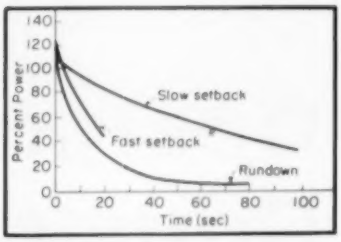


FIG. 6. Curves of power vs time for automatic power reduction sequences

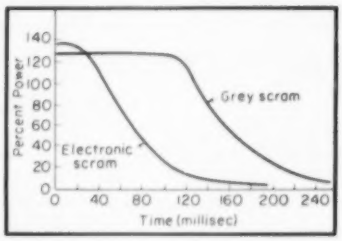


FIG. 7. Curves of power vs time for Engineering Test Reactor scrams

Instrumentation

There are six basic instrumentation channels: flux limit, log N-period, restart, automatic flux, process monitoring, and deviation galvanometer. The instrumentation system largely follows that used on the MTR.

The flux-limit safety channels monitor in-pile uncompensated ion chambers so as to record gross flux in the reactor. The log N-period channel monitors the log of reactor power and the generated reactor period. The restart channels monitor the startup to provide information as to the point of criticality. This involves count-rate circuits for routine startup, startup period, startup log power, and circuits to control the positions of the fission chambers within the reactor (withdrawing them as the flux increases). The automatic flux channel maintains (within the regulating rod limits) the reactor flux at a predetermined level by regulating the position of one of the two servo-controlled regulating rods. The process-monitoring circuits cover such parameters as water flow, temperature, pressure, etc. The level galvanometer channel provides an accurate indication of change in reactor power level.

Pressure Vessel

The vessel is designed for water at 250 psi and 200° F. Inlet coolant flow is through a single 36-in. nozzle opening into an internal flow distributor. Outlet is through another 36-in. nozzle. A discharge chute in the transition piece provides for passing fuel elements between the vessel and canal. (For pressure-vessel details see p. 48.)

Thermal Shielding

Internal thermal shields reduce the radiation fluxes to magnitudes that will not produce excess thermal stresses in the vessel wall. The internal shields are made of four cylindrical iron plates with associated water layers. For economical reasons, more steel than necessary to protect the vessel walls was added to the internal thermal shields. This reduced the amount of steel required in the external thermal shield.

External thermal shields protect the concrete biological shields (described on p. 53) from excessive heating. The external thermal shield is composed of $3\frac{1}{2}$ in. of lead with stainless-steel cooling coils embedded in it. It is designed to maintain the inside surface of the concrete biological shield below 120° F.

Fuel Handling

It is expected that the ETR will be refueled after every 17 days on line. Three days are allotted for refueling and tending experiments. Actual times will depend on operator techniques and experience and on schedules. A 2-hr cooling period is sufficient to permit manual refueling from positions on a platform fitted over the vessel following removal of the top head. While refueling, enough water is in the reactor vessel so that the refueling crew is protected from overexposure to radiation. The top of the active portion of the element remains at least 78 in. below the water surface at all times.

Fuel and control-rod elements removed from the core are dropped into the discharge chute in the transition piece. The elements pass out of the discharge chute into a mechanical transfer tube. The tube "flops" the element into the canal, where it is grappled into a storage rack.

Experimental sections up to 15.6 ft long can be handled through the discharge chute by removing the transfer tube. Sections longer than 15.6 ft must be pulled out the top.

etr: Design and Construction

In May ETR will go critical, only two years from start of design. Here's how it was done—the story of testing and selecting metals for vessel and piping and cement for shielding and of solving some unusual construction problems

By PHILIP D. BUSH, *Kaiser Engineers, Oakland, California*

THE ETR DESIGN evolved in part from a conceptual design prepared by the Phillips Petroleum Co., operators of the Materials Testing Reactor at Idaho Falls. In 1955 the Atomic Energy Commission awarded prime contracts to Kaiser Engineers for design and construction. Kaiser, in turn, issued a subcontract to General Electric for design of core and controls. When the reactor goes critical in May, it will have been two years since the start of design and a year and a half since start of construction.

What Did ETR Cost?

The total cost of the ETR facilities is $17,200,000 including engineering, development, and construction. The original budget for the work was $18,500,000. A breakdown is as follows:

Reactor and control instrumentation	$2,900,000	
Reactor building	2,200,000	
General experimental facilities and services	2,100,000	
Coolant systems and associated buildings	4,200,000	
Electrical	2,100,000	
Winter protection	300,000	
All other	800,000	
TOTAL CONSTRUCTION		$14,600,000
Engineering, development, and inspection		2,600,000
GRAND TOTAL		$17,200,000

The reactor is shown in Fig. 1, and Fig. 2 is a cross-section view of the reactor vessel and its contents. It is fairly standard except that the control rods are driven from below and the access holes form the basis for through-pile loops. The primary purpose of having the control rod drives below the vessel is to leave the area above the core as free as possible for the use of the experimenters. With through-pile loops the experimenter can circulate a fluid continuously from the core region into experimental cubicles in the building basement, or he can maintain his experiment completely within the reactor vessel.

The ETR facility consists of such major equipment as a reactor, storage canal, primary and secondary coolant systems, experimental facilities, associated buildings, and extensions to existing utilities. As shown in Fig. 3 it is located adjacent to the MTR at the National Reactor Testing Station. Thus it has not been necessary to build many supporting facilities such as laboratories and shops but only to build extensions to many other existing facilities.

Figure 1 gives the reader an idea of the relative positions of vessel, canal, sub-pile room, and control-rod-access room. Experimenters' equipment will be designed to make a right-angle bend upon leaving the bottom head of the reactor and leave through the sub-pile room into the cubicle areas of the basement floor. In general there will be little experimenters' instrumentation and control equipment on the basement floor as the console floor is reserved for this use. Experimenters' equipment on the basement floor will consist of heat exchangers, pumps, motors, and things of that nature.

Control-rod-drive mechanisms will be serviced from the control-rod-access room. The abnormal height of this room makes it possible to remove large sections of control-rod extensions intact. Radioactive materials such as fuel elements, experimental equipment, control rods, and the like, will be removed from the vessel through the discharge chute and stored in the canal for subsequent disposal.

PRESSURE VESSEL

From the start it was apparent that the most critical item requiring early design would be the reactor vessel. The dimensions had to be settled as early as October 1955 to determine how much excavation had to be made for the reactor building.

The vessel is of reasonably conventional design. It is ~35 ft long, 12 ft in upper diameter and 8 ft in lower diameter. (See Fig. 2.) Design pres-

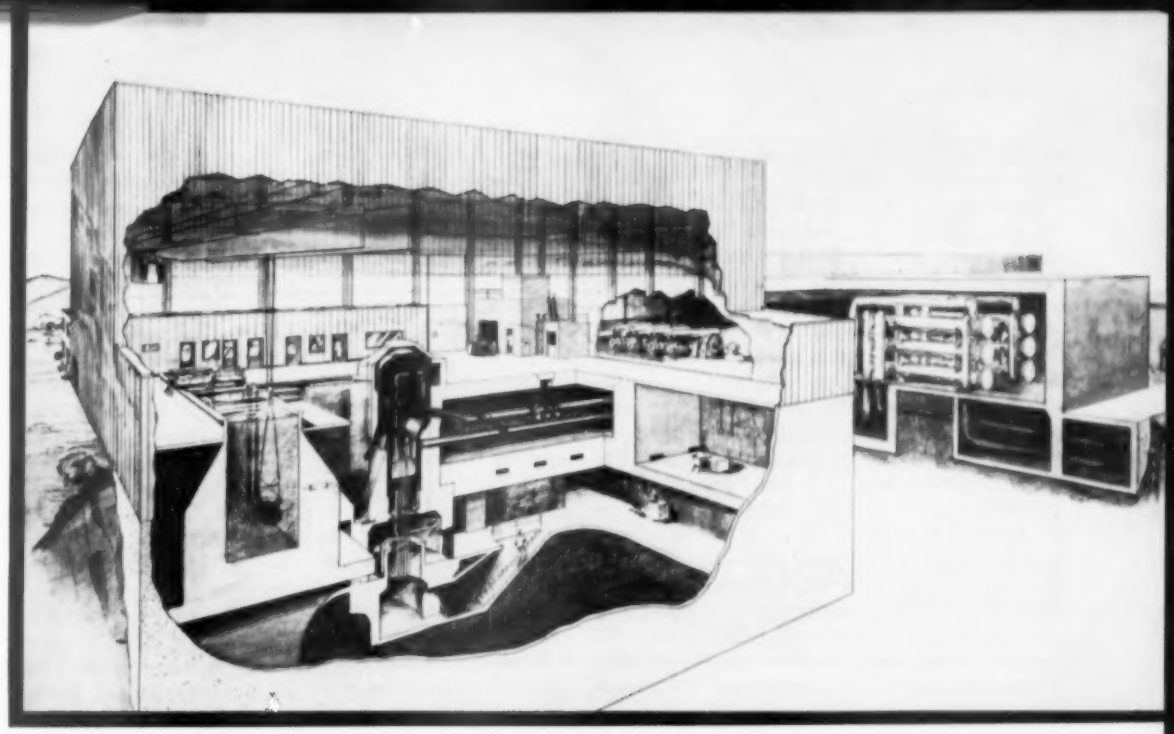


FIG. 1. Cutaway view of ETR. Canal for removal of radioactive materials is to left of pressure vessel. Steps lead from control-rod-access room to basement floor. Man at desk is on console floor. Sub-pile room is between reactor and control-rod-access room. Large pipes to right of pressure vessel are coolant-water inlet and outlet

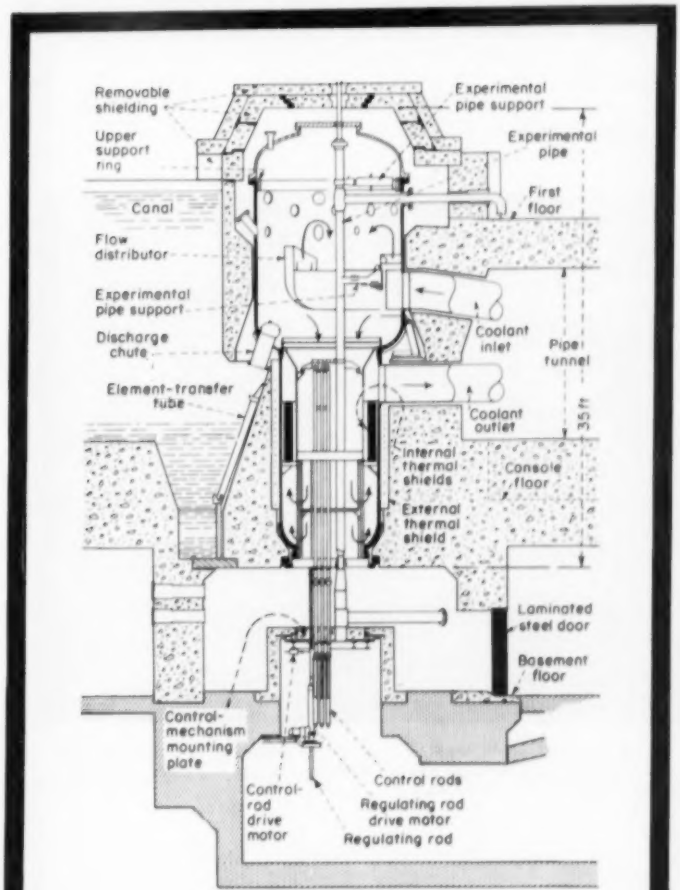
sure is 250 psig at 200° F. Weight of the bare vessel is 150,000 lb; operating weight is approximately 350,000 lb. Water circulates through the vessel at ~44,000 gpm, developing thrusts up to 22,000 lb on the shell at the inlet 36-in.-diameter pipe.

Fabrication. Conventional methods were followed for fabrication. Cylinders were rolled from plates and welded in accordance with the ASME code for unfired pressure vessels. The top head is elliptical, with nozzles and flanges attached in the usual manner. Material is carbon steel clad on the inside with type-304L stainless steel.

Techniques more refined and more particular than required by the code were specified in a number of instances —ultrasonic testing of all materials, 100% radiographic inspection, dye testing, and magnetic-particle testing of all forgings and welds. Fabrication tolerances for parallelism, ovalness, flatness, alignment, etc. were considerably more stringent than required by the code.

Although the vessel will bear the official code stamp, the code served only as a minimum standard, with a complete stress analysis covering every component of the vessel. During the course of our evaluation several errors were discovered in certain generally accepted standard references. The

FIG. 2. Cross-section view of reactor. Disposal canal is to left of pressure vessel. Coolant pipes enter at right. Below vessel are sub-pile room, control-rod-access room, and control-rod drives



authors have agreed to correct the errors in their next editions.

Bottom head. The bottom head of the vessel provides for penetration by experimenters' tubes and control rods. These are sealed against pressure by stuffing boxes monitored for leakage, and yet they allow for movement due to temperature changes. It is possible to remove these tubes, control rods, and all other items penetrating the bottom head without loss of any water.

Altogether there are 37 holes through the bottom head, ranging in size from 2½ in. to 6 in. in diameter. All these are within a diameter of 36 in. in the central portion of the head which is 65 in. in diameter and 8½ in. thick. The mechanical and pressure loads on this head total over 1,300,000 lb. This is about the same as a railroad train of thirteen 50-ton cars stacked on the perforated bottom head. In addition, when the sixteen control rods scram simultaneously from the highest position, an impact load of 160,000 lb is imposed on the center of the head.

The penetration of many experimental and control tubes makes the bottom head look like a large cake of Swiss cheese; more than 20% of the head volume consists of voids. In the central portion of the bottom head more than 40% of the metal is removed. Some of the ligaments between holes are only 1⅜ in. wide. The points of highest stress in the vessel occur at these ligaments with a stress of 21,000 psi when the control rods are scrammed. This will give some idea of the need for a complete stress analysis.

VESSEL SUPPORTS

The problem of supporting the pressure vessel is one of holding a vertical load of approximately 252 tons in such a manner that thermal expansion will not introduce stresses or movements of the vessel or coolant-water headers that would be dangerous or objectionable.

Many complications resulted from the desire for bottom control-rod drives. Drive mechanisms became so long that the rods extended through the subpile room immediately beneath the vessel and into a sub-subpile room (control-rod-access room) blasted out of the solid lava 25 ft below the vessel's bottom head. Since these rods are supported from the vessel head at one point and from the building structure at another, a problem of possible misalignment was created in case the vessel were to move due to expansion or loading. A few thousandths of an inch could raise the possibility of binding the control rods and preventing their drop to the scram position, an intolerable hazard. Collaboration between structural and mechanical designers resulted in vessel supports that allow movement but carefully control its direction, and also a vertically sliding joint for the roll guides.

Since the vessel has a transition from a large diameter to a small one midway between inlet and outlet coolant headers, the support under the transition is midway between the header pipes so that they will have equal vertical movements under thermal expansion.

The supports as finally designed rest on the concrete of the biological shield and give relatively uniform support all around the transition piece of the pressure vessel. In addition to supporting the vertical load, the supports provide for radial expansion, and the vessel is guided at the lower end to assure that it will not rotate about its vertical axis and that the vertical axis will remain vertical.

Design Loads

The pressure-vessel supports will carry the weight of the vessel and everything inside it, the top head, and the shock of the control rods under scram conditions. These loads are roughly as follows:

Vessel, heads, and internal thermal shields	75 tons
Water and internals	82
User facilities	15
Control-rod shock load	80
TOTAL	252 tons

Problems Involved

The problems involved in designing the supports include the following:

1. Allow radial and vertical thermal expansion without displacing the pressure vessel and "binding" the control rods, which protrude from the bottom.
2. Minimize movement of coolant header pipes.
3. Give uniform support all around the vessel and distribute the load so as not to concentrate stresses in the transition piece.
4. Provide support that expands with the vessel and maintains uniform contact with it.
5. Allow for erection without exact tolerances in the support construction and still position the vessel exactly.
6. Keep the subpile room clear of structural columns, bracing, etc.
7. Allow thermal expansion without "binding" the vessel and introducing stresses for which the vessel is not designed.
8. Provide a system that does not require maintenance since it is inaccessible after installation of the biological shield.

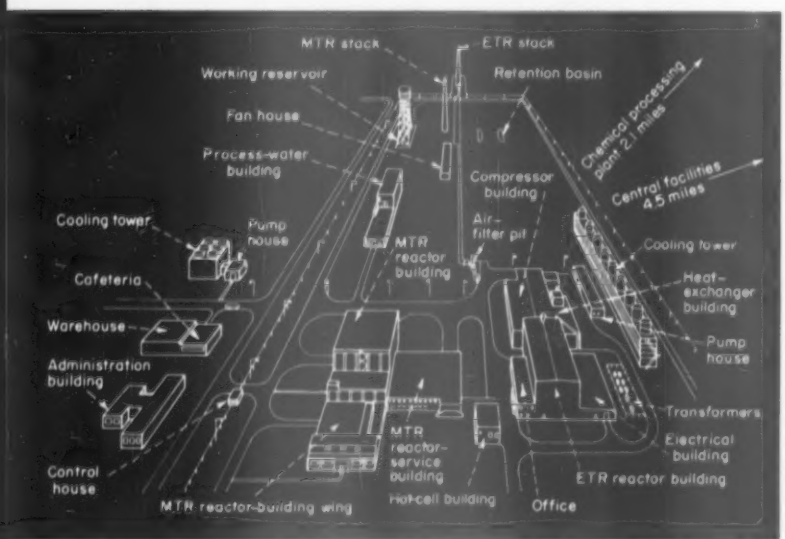


FIG. 3. ETR stands south of MTR and shares many of its facilities. Both gaseous-waste stacks are shown at top. ETR pump house and cooling tower are at extreme right

Support Design

Figure 4 shows the details of the pressure vessel supports at the transition piece. The support bed plate is continuous and will not "open up" under thermal expansion of the vessel. There are a total of 20 individual support points for the vessel and they are fairly uniform in spacing. Spanning plates welded to the vessel distribute the load to the vessel over a large area. Vessel and supports will expand together and not separate to give support on just one edge. The pressure on this plate is about 50 psi, and this is reduced somewhat by the fact that the "U" bars are welded to the thick portion of the bottom cylinder of the vessel near the base of the transition piece.

The 20 support points rest on a total of 34 expansion plates, so that there is a unit load of only 400 psi. These plates are self-lubricating bronze-alloy plates made especially for such applications. They are capable of supporting a unit bearing pressure of 1,200 psi and a temperature of 550° F. The factor of safety of 3 gives provision for the fact that the load may not be uniform for each shoe. The supports at the discharge chute are carried by a girder spanning the region of the chute, which has no concrete below it for supporting load. The large structural angles connecting guide shoes give the system stability against lateral forces and rotation of the vessel. The angle welded to the vessel is for installation; it acted as a surface to shim against before making the final field welds between vessel and its supporting shoes.

Thermal Expansion

The expansion of the pressure vessel will be approximately 0.11 in. radially for a temperature change of 150° F. This expansion is maintained by guide studs in slotted holes which will allow radial expansion only, since they are distributed around the perimeter of the vessel.

The bottom head of the pressure vessel is to be kept on a horizontal plane within a tolerance of ±0.001 in./ft. This tolerance was taken care of in the erection of the vessel; the vessel was lowered into position, leveled to the prescribed tolerance, and located concentrically before the vessel-support shoes were field welded to the vessel. After the support shoes were welded, a structural angle was field welded to fasten all the shoes together, providing stiffness and stability for torsional movements.

The entire vessel is free to expand radially under thermal expansion and vertically each way from the support shoe. The location of the support shoes midway between the inlet and outlet coolant pipes minimizes movements of these large pipes.

As a further aid in maintaining the vessel in a vertical position, there are four guide lugs at the lower end of the vessel that allow vertical movement but not rotation or horizontal movements. These lugs were field welded to the vessel after it was aligned to the erection tolerance. The tolerance between the guide lug and slot is 0.003 ±0.002 in. The slot is fastened solidly to the shielding concrete.

TABLE 1—Estimated Cooling-System Costs

Case	*Capital cost ($10⁶)*	*Annual amortization (9%) ($10³)*	*Annual operating expense ($10³)*	*Total annual cost ($10³)*
1. Cooling tower, aluminum shell and tubes	2.42	218	326	544
2. Cooling tower, carbon-steel shell, and stainless-steel tubes	2.58	232	296	528
3. Fin-fan, aluminum	4.92	443	515	958
4. Fin-fan, stainless steel	6.47	582	458	1,040
5. Flash evaporator, aluminum shell and tubes	3.55	320	420	740
6. Flash evaporator, carbon-steel shell, and stainless-steel tubes	3.70	333	376	709
7. Spray pond, aluminum shell and tubes	2.50	225	350	575
8. Spray pond, carbon-steel shell, and stainless-steel tubes	2.77	249	316	565

PRIMARY COOLANT SYSTEM

The primary coolant system is based on a reactor inlet at 110° F, 44,000 gpm, and 200 psia. Means have been provided to eliminate the possibility of any gas-bubble formation in the core and to prevent boiling in the core after all credible accidents. Demineralized water in the primary loop passes through the reactor on the tube side of shell-and-tube heat exchangers. The secondary loop rejects the heat to the atmosphere through a cooling tower.

In the interest of economy it is desirable to have the primary coolant leave the reactor at as high a temperature as possible in order to have a high log-mean-temperature-difference between primary and secondary systems in the heat exchangers. At the flows contemplated, calculations indicate that primary-coolant temperature at the inlet to the vessel should be no higher than 110° F in order to insure against burnout of fuel elements under certain assumed emergency conditions. Calculations of this sort are extremely rough, and it is possible that higher outlet temperatures can be used with safety. However, in order to justify a higher design temperature, an elaborate and expensive test program would have been required. This might or might not have justified a higher coolant temperature for the design, which calls for a maximum heat flux of 1,150,000 Btu/ft²/hr.

No reactor to date has approached these conditions under normal operation, and there is little experience on which to make any conservative extrapolation. This situation creates a real problem as raising the inlet temperature from 110 to 130° F would result in a saving of approximately $200,000 in the primary-coolant system. Under normal conditions a spare bank of heat exchangers would have been installed in order to run the reactor at full power during maintenance of one bank. At the present time the $200,000 has been saved by eliminating the spare bank while still leaving room in the heat exchanger building in case it is needed. During the first year of reactor operation, tests will be run to confirm the heat-transfer characteristics of the core. This eliminates the need for an expen-

sive out-of-pile test program to determine whether the coolant-inlet temperature can be raised from 110 to 130° F. If the tests are favorable toward 130° F, the present facilities will, in essence, include a spare bank of heat exchangers, resulting in a saving of $200,000.

System studies. Various types of coolant systems were studied in order to obtain the one most economical for ETR. Table 1 shows a summary of estimated costs based on both operating costs and annual amortization at 9% of capital cost. The cooling-tower–stainless-steel-heat-exchanger combination in Case 2 gave the lowest annual cost, and therefore it was selected. In comparing stainless-steel and aluminum heat exchangers there are several intangible advantages for stainless steel such as more experience in a nuclear environment and the fact that considerably less primary coolant has to be bypassed through demineralizers to maintain the ½-ppm impurity desired. There is also a smaller radioactive-waste-disposal problem.

Operation. A simplified flow diagram of the primary coolant system showing the pressurizing and degassing equipment is shown in Fig. 5. Pressurizing is accomplished by continuously pumping water into this system and withdrawing it at such a rate as to maintain and control pressure. The pressurizing pump takes water out of the degassing tank and pumps it into the system through a flow-control valve set for 300 gpm. The surge tank, which will be filled with air to ⅔ of its volume, serves as a cushion on the system during normal operation so that the pressure is easier to control within a small range. It also serves an important function as a source of emergency water and pressure.

Gas evolution in the core must be prevented to maintain the heat transfer coefficient as high as possible. The degassing tank can be operated either at atmospheric-pressure or vacuum. Based on both theoretical considerations and experimental data, it has been predicted that the equilibrium gas concentration of H_2 and O_2 would be ~ 5 cm³/liter,* which is far less than the system's minimum solubility of 160 cm³/liter at the primary pump inlet.

* Concentration is expressed in terms of the volume occupied by the gas at standard conditions.

Degassing tank. There are several reasons for including the degassing tank. First is that there is no actual operating experience in the use of water of as high purity as ½ ppm of dissolved solids in a reactor like ETR. Second, the tank will remove noble fission gases in the event of a fission break. Third, it will remove carbon dioxide formed by oxidation of any organic material in the system and hydrogen resulting from corrosion.

Air will be blown across the water spray entering the tank to strip gas from the water and prevent accumulation of an explosive mixture of hydrogen and oxygen; the exhaust gases will be vented to a stack.

MATERIALS, FABRICATION

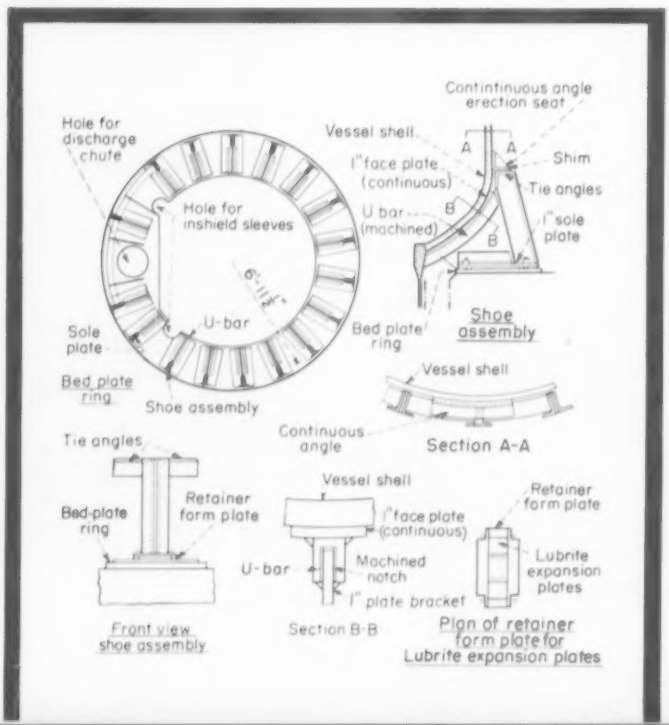
Materials for the system are mainly ferrous. The pressure vessel is of stainless-clad carbon steel. Primary coolant piping is of solid 347 stainless, and the pipes of the heat exchangers are 304 stainless. Pumps have carbon-steel bodies and austenitic stainless impellers.

Primary-coolant piping. The selection of materials exposed to the primary coolant was based on a desire to maintain the water at a maximum of ½ ppm dissolved solids and exposure to water at a *p*H of 6, a temperature of 138° F, and a maximum pressure of 250 psia. These conditions indicate an environment favorable to a satisfactory service life for aluminum-clad fuel elements. However, when one considers aluminum alloys for the primary-loop pipe and heat-exchanger tubing, the low allowable design stress requires a wall thickness that raises fabrication costs above those of comparable ferrous systems. Furthermore, a corrosion rate ~25 times that for stainless steel meant that a considerably more expensive bypass demineralizer plant would have been necessary. The high activation cross sections and long half-lives of corrosion inhibitors make these water additives undesirable for a reactor with such a high flux as the ETR. For the same reason copper and bronze alloys could not be considered as materials for the primary coolant system.

Intergranular corrosion at the welded areas will be eliminated by the use of stabilized 347 stainless steel. The problem of stress-corrosion cracking, which is largely dependent on the chloride concentration of the secondary water, is minimized by almost complete absence of weld pockets in heat exchangers and piping.

Economic analyses showed that in the thin-walled large-diameter pipe pieces, solid stainless steel is cheaper than stainless-clad carbon steel. The economic break-even point appeared to

FIG. 4. Pressure-vessel support is accomplished at the transition piece between top and bottom sections. Spanning face plates welded to vessel distribute load. Shoes transfer force from transition piece to bed-plate ring on concrete



be with a material thickness of approximately ¾ in. Thus for the primary-coolant piping, the material specified was solid stainless steel and for the vessel, where wall thicknesses were 1 in. and 2½ in., stainless-clad was selected.

Pumps. With respect to the pumps, the relatively small area of the pump bodies exposed to the primary coolant as compared to the entire system indicate that cast carbon steel is satisfactory both from the standpoint of service life and the negligible amount of corrosion products entering the system. For reasons of service life the impellers are made of austenitic stainless steel. A recent quotation for a 20,000 gpm pump shows a saving of $10,000 for a pump with a carbon-steel body compared with one of stainless steel.

Heat exchangers. The heat-exchanger tubes are made of 304 stainless steel and shells are of carbon steel, the latter being satisfactory for the secondary coolant system.

Grid plate. One of the major material problems encountered was that of procuring an adequate grid-plate forging. This item is a large forged disk of solid stainless steel 9 in. thick and 65 in. in diameter. The forging weight is 9,000 lb, and the finished weight, 6,000 lb.

It was possible to secure bids for this forging from only two firms. The firm selected forged two disks from the same top-pour, hot-topped ingot. The ingot was cut into two parts, each part flattened, and the corners bumped down to form the rough disk. Ultrasonic examination showed both disks to be defective in and around the central areas.

After drilling proved the ultrasonic indications, the disks were rejected and the supplier poured another ingot. However, this time a larger section from the bottom of the ingot was flattened, and the corners were not bumped as before. Ultrasonic examination revealed only minor defects that could be machined out during the final preparation. In a way this was one compensation for having so many holes through the grid plate.

When the AEC was interested in obtaining a spare grid plate, the smaller remaining portion of the ingot required corner bumping to form the plate. Unfortunately, the corner bumping again resulted in forging bursts similar to those that occurred in the first two disks, and no spare grid plate was obtained.

Fuel plates. The fuel plates are flat and 3 ft long. Boron has been incorporated in the cladding as a burnable poison. Corrosion and stability tests in the MTR indicate that no unusual problems will be encountered with a boron-aluminum alloy. During the development stages, both furnace and dip brazing of the plates to the side plates were investigated. Previously the MTR elements have been prepared by furnace brazing. However, it appears that dip brazing promises considerable economies in preparation. Although all the acceptable brazing fluxes contain lithium chloride, the quantity entrapped in the fuel elements is so small that the high neutron-capture cross section of the lithium and the resulting helium were not considered significant problems.

SHIELDING

The system has essentially four shielding problems: The concrete shield is for protection of personnel from gamma rays and neutrons. Inside this are five thermal shields, one outside the pressure vessel and four inside it. These are to protect biological shield and pressure vessel from excessive thermal stress. There is the shielding of the radioactive primary coolant, and finally there is the problem of handling spent fuel.

Thermal Shielding

There are four internal, concentric, cylindrical thermal shields made of 304 stainless steel. They have a combined thickness of ~4 in. The four are cooled by the primary coolant, which flows first down through the core and then up through the thermal shields and out of the reactor pressure vessel.

In order to reduce radiation incident on the concrete biological shield still further, an external thermal shield is placed between pressure vessel and concrete shield. This thermal shield is of 3½-in. lead and has stainless-steel cooling coils embedded in it. Primary-coolant water is circulated through these coils to remove the 400,000 Btu/hr expected in the shield. The design of this shield has been most carefully worked out with every possible precaution for uninterrupted water cooling, for once the reactor is in operation it will be impossible to service it without a complete dismantling of the entire core and removal of the vessel.

The relative amounts of radiation absorbed by the shields are as follows:

1. Internal thermal shield—2,000,000 Btu/hr
2. External thermal shield—400,000 Btu/hr
3. Concrete biological shield—4,000 Btu/hr.

Coolant Shielding

Several nuclear reactions make coolant water radioactive. Most important from the point of view of shielding are the ones that form N^{16} and Na^{24}. Both of these isotopes have long enough half-lives and sufficiently energetic gamma rays to require shielding of the coolant piping.

N^{16}. The $O^{16}(n,p)N^{16}$ reaction produces 7-sec N^{16}. This is not a long-lived activity. However, it does have a 7-Mev gamma and must be shielded if the delay time between leaving the core and entering an inhabited area is less than ~2 min. For the ETR, the total primary-coolant-cycle time is slightly over 1 min so the cooling water requires shielding throughout the cycle. Between reactor vessel and heat-exchanger building, primary-coolant pipes are in a 50-ft tunnel that has a minimum of 4 ft of high-density concrete shielding in all directions.

Na^{24}. Radioactive sodium has two different origins: (1) Natural Na^{23}, present in the water as an impurity, absorbs a neutron to become Na^{24}. (2) The aluminum atoms in the cladding of the fuel elements will, upon absorption of a fast neutron, eject an alpha particle leaving a sodium atom [$Al^{27}(n,\alpha)Na^{24}$]. If the aluminum atom is near enough to the surface of the metal that is in contact with the cooling water, the recoil energy of the reaction is enough to eject the radioactive sodium atom into the water. The radioactive sodium has a 15-hr half-life; consequently this radioactivity is still present long after the N^{16} activity has disappeared.

The high-purity ETR cooling water will contain approximately 0.25 ppm of natural sodium as an impurity. Calculations show that 10% of the sodium activity results from this impurity and 90% from recoil sodium. Total sodium activity is 10,000 dps/cm³. We believe this relation can be extended to other reactors with the same type of primary coolant system.

Biological Shield

As a rough approximation, the required thickness of a biological shield

is inversely proportional to its density. High-density concrete was used to reduce dimensions and allow more working area. The type of aggregate used is ordinarily determined by economic considerations. Typical aggregates used in reactor shielding are barytes, magnetite, and ferrophosphorus.

Certain types of aggregates will produce secondary gamma radiation with neutron absorption. This is especially true with magnetite, an iron ore composed primarily of iron atoms. Capture gammas from iron have very high energy—7.8 Mev (*1*)—and consequently this source of radiation must not be ignored in shielding design. For example the use of magnetite concrete in the biological shield requires approximately 8 ft of shielding, whereas if barytes were used, a thickness of 7 ft would have been satisfactory. However, the lower cost of magnetite concrete offset the cost of the additional foot of floor area. The shield was designed to attenuate radiation to $\frac{1}{10}$ tolerance.

Requirements for concrete. The ideal concrete for a reactor shield is one with maximum density for gamma shielding and as much hydrogen as possible, usually in the form of water, for neutron shielding. If there were no other requirements, these could easily be met with a mix based on minimum sand, maximum large aggregate, high water content, and minimum cement. However, such a mix would certainly segregate badly and have excessive bleeding. Paradoxically this would make the concrete even better for those simple requirements, since the large aggregates would pack down into a tighter mass as the paste bled out to the top of the mix.

However, for ETR the requirements are not quite this simple. A massive block is not enough. The operating temperature differential through the shield (~60° F) induces axial and tangential stresses that necessitate a certain amount of strength. Various embedded items in the shield require that segregation and bleeding be held to a minimum to prevent the formation of gaps in the shielding underneath embedded items. The concrete must be workable in order that it move easily into intricate passages and around the embedded items. Bleeding can be minimized by the correct choice of mix.

Some of the concrete requirements are mutually incompatible. Reduced segregation and increased workability were accomplished simultaneously at the expense of reduced density. At first it seemed like a relatively easy matter to vary the strength by simply varying the cement content. Trial mixes quickly proved, however, that the cement had a dual function in heavy-concrete mixes: It not only is the strength element in the hardened concrete, but it also is needed in the fresh concrete to float the heavy aggregate particles and provide the mix with workability and cohesion. In addition, the flat, angular, and elongated shape of the aggregate, including even the finest sand, required that the paste be able to lubricate all particles more than usual for normal workability.

Out of all the trial mixes made, one principle emerged: To make a workable heavy concrete, the large particles must be floated in a dense, tough mortar. This eventually meant minimum water consistent with required slump, and maximum amount of fine particles, in the form of either cement, air, or inert admixtures. Since air reduces density, and cement increases strength beyond the required values, a pozzolanic admixture was needed to obtain optimum density, workability, and strength.

Stress conditions. The stresses in concrete depend on the temperature gradient through the shield and such properties as compressive strength, modulus of elasticity, energy-absorption coefficient, and cyclic growth. With the reactor in operation the temperature gradient gives compression on the inside face and tension on the outside face of the shield. The maximum concrete temperature is estimated at 136° F approximately 1 ft in from the surface closest to the reactor.

Regarding the principal sources of stress, only about 100 psi is caused by the temperature gradient across the shield due to radiation heating. The remaining 500 psi is caused by the gradient due to the temperature difference between the external thermal shield and ambient.

Growth. Truly the greatest problems concerning the use of high-density concrete are growth on thermal cycling and uniformity of density throughout the shield. For any given concrete mix containing normal cement with high-density sand and aggregate, a test program must be effected in order to solve both of these problems before design can be completed. The cost of such a program is generally nominal. The ETR program cost less than $4,000.

If a mix is subject to excessive growth on thermal cycling (and one cannot eliminate thermal cycling with reactors that must be shut down periodically), the shield will crack and allow radiation streaming. In any event, sufficient reinforcement must be added to compensate for whatever stresses will be present due to growth from thermal cycling.

With the particular grade of magne-

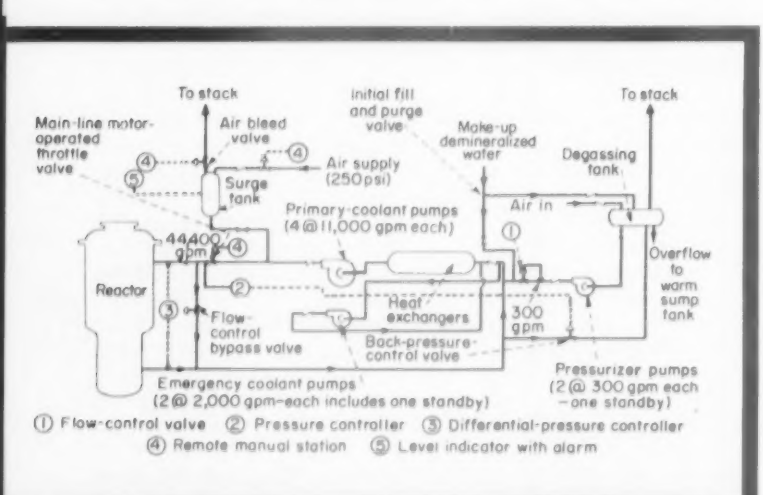

To stack
Initial fill and purge valve
To stack
Main-line motor-operated throttle valve
Air bleed valve
Make-up demineralized water
Degassing tank
Air supply (250 psi)
Surge tank
Air in
Primary-coolant pumps (4 @ 11,000 gpm each)
44400 gpm
Overflow to warm sump tank
Reactor
Heat exchangers
300 gpm
Flow-control bypass valve
Back-pressure-control valve
Pressurizer pumps (2 @ 300 gpm each —one standby)
Emergency coolant pumps (2 @ 2,000 gpm—each includes one standby)
① Flow-control valve ② Pressure controller ③ Differential-pressure controller
④ Remote manual station ⑤ Level indicator with alarm

FIG. 5. Schematic diagram of primary-coolant circuit. Emergency pumps will maintain circulation in event of failure of primaries. One air system flushes degassing tank to remove any gas accumulated in system. Another maintains water level in surge tank

tite ore used, the growth on thermal cycling as shown in Fig. 6 was no more than one would obtain from various standard materials. As a comparison, the rate of growth on thermal cycling of the concrete at the Conowingo Power Plant in Pennsylvania is shown (*2*). The concrete there gradually expanded under the influence of temperature cycles and caused binding of the control valves in the power plant.

Mix used. With respect to proper mix, one must determine a range of water-cement ratios and sand content so that construction forces will have a workable mix that will not segregate or bleed. Based on the test program, a normal working range was developed. In the field the average density was 219 lb/ft³ in a range of 215–224 lb/ft³. When the cement content was reduced from 5.5 sacks/yd³ to 5.0 sacks/yd³ in some trial batches, there was segregation and loss of density. Such standard liquid admixes as Protex and Pozzolith also resulted in segregation and loss of density. Even during the worst of the winter months when the temperature dropped to 30° below zero, it was imperative that concrete temperatures be kept in the range of 60–75° F during pouring, and a minimum allowable air temperature of 50° F was maintained during setting.

Average cost for 4,000 cubic yards of high-density concrete was $160 per yd³. This includes forms, stripping, reinforcing, placing, and finishing of both the biological shield and the walls of the pipe tunnel.

Spent-Fuel Shielding

Approximately 30% of the uranium in a core loading will have fissioned in a 20-day cycle. The resultant fission products present in the elements will produce decay heat, and consequently the elements, about 70 per core loading, must be cooled and shielded. This cooling is accomplished by storing the spent elements vertically in the ETR storage canal and allowing natural circulation to remove the decay heat. The storage racks hold 36 elements each and will occupy approximately 25 linear feet of the storage canal.

GASEOUS-WASTE DISPOSAL

Proper handling of gaseous wastes under all conditions requires (1) a carefully designed ventilation system for the building and (2) an exhaust stack so designed and located that no hazard results from its effluent regardless of the nature of reactor operation and meteorological conditions.

Ventilation

The building has two separate ventilation systems, one for the first floor and another for console and basement floors. The system for the first floor consists of outside-air intake louvers, mixing dampers, washable filters, steam heating coil, recirculating blower, and an exhaust fan in the roof. The air circulation rate is equivalent to four volume changes per hour. Half of the circulation is fresh outside air and half is recirculated air. The exhaust air is discharged at the top of the building through a quick-closing damper.

Console and basement floors are ventilated by a common system. The circulation rate for the console floor is six changes per hour. Approximately half of the air is recirculated. Equipment for mixing, heating, etc., similar to that used for the first floor is provided. Half of the air from the console floor passes down into the basement floor and passes into the experiment-cubicle area through leaks around cubicle doors, pipes, and openings. Cubicles are exhausted through a duct provided for this purpose. This system maintains the cubicles at a lower pressure than the console floor. Exhaust air from the cubicles is discharged to the stack.

A system of controlled exhaust in the subpile room and control-rod-access room creates negative pressure in these areas. Inlet air enters the subpile room by leakage around the vessel and the plugged experimental openings. The control-rod-access-room inlet air consists of leakage from the control-rod mounting plate and the entrance door. The common exhaust ducts from both rooms are connected to the cubicle-exhaust system. In the event of an incident, the damper to the roof vent will close within 15 seconds while the stack remains operative.

A 1-in. space separates the upper portion of the reactor vessel from the surrounding concrete shield. Air from this volume is sucked into the sub-pile room and passes into the cubicle exhaust.

Stack

A stack is required to dispose of contaminated air coming from the following sources:

1. Spills leading to contamination of the ventilation air.
2. Degassing of the primary coolant water.
3. Radio-argon generated continuously in air-cooled experiments.
4. Failure of a fuel element in a gas-cooled experiment.

There are four general criteria for exhaust stacks handling radioactive effluents:

1. A filter should be installed ahead of the stack for removal of radioactive particles.

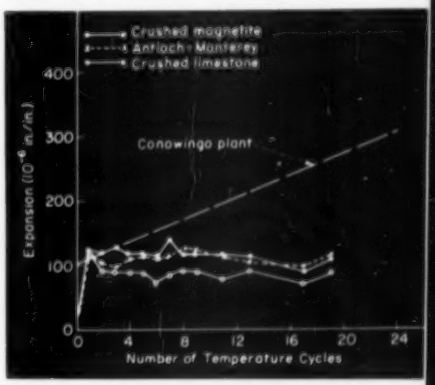


FIG. 6. Thermal growth of three satisfactory concrete mixes can be compared with growth observed at Conowingo power plant (2)

2. The stack should be located downwind of occupied areas if there is a prevailing wind direction.
3. The stack should be high enough that air discharged is substantially above the top of buildings and structures to prevent local eddies from carrying contaminated air down to the ground.
4. The combination of distance (between stack and occupied areas) plus stack height should be set so that during "looping" conditions, when the stack effluent is carried down to the ground, the concentration of radioactive materials will remain within safe limits.

Application of these principles at ETR resulted in location of the stack generally east of the ETR-MTR site (Fig. 3). As a result only winds from the ENE to SE sector carry effluent from the stack over occupied areas at the site. The winds blow from this quadrant less than 7% of the time. The stack is 250 ft high and about 500 ft due east of the nearest occupied area.

As a result of this stack location and

TABLE 2—Bids and Deliveries of Major ETR Components

Component	Number of bidders	Lowest acceptable bid	High bid	Delivery	
				Promised (mo)	Actual (mo)
Reactor vessel	12	$338,000	$532,000	10	14
Reactor instrumentation	4	265,000	577,000	9	10
Cooling tower	3	292,000	292,000	5	5
Control rods and drives	4	187,000	600,000	5	7
High-pressure compressors	4	531,000	558,000	6	9
Heat exchangers	11	452,000	700,000	5	7
Grid-plate forging	2	19,600	20,200	1.5	1.5
Grid-plate machining	2	55,000	60,000	6	6
Fuel elements (each)	3	358	1,645	6	6
15,000-kva transformers	4	232,000	267,000	6	7
Switchgear	4	222,000	228,000	4	4
15,000-gpm pumps	4	76,000	116,000	7	9
36-in. stainless piping	4	55,000	74,000	4	8

height, the ground-level argon-41 concentration resulting from an air-cooled experiment could be as much as 1–2 × 10^{-5} mc/liter during adverse atmospheric conditions such as "fumigation" or "looping." An explanation of these terms follows.

Fumigation by the stack effluent plume occurs when a temperature inversion is present just above the top of the stack. This acts as a lid, and convective eddies mix the effluent plume in the shallow lapse layer near the ground. With this condition large concentrations are brought to the ground along the entire effluent stream. Strong effluent concentrations can also be brought to the ground, at least briefly, at great distances from the stack. Fumigation also gives stronger sustained ground concentrations in the neighborhood of the stack than the other conditions. For this reason fumigation constitutes the greatest hazard to the surrounding area.

Looping by the effluent plume occurs with a large vertical temperature gradient in the air. Gases diffuse turbulently, and sporadic puffs having strong concentrations are occasionally brought to the ground near the base of the stack. Another condition like looping probably results when the wind blows from a relatively smooth terrain over a built-up area leading to considerable mechanical turbulence.

The A^{41} figure of 2 × 10^{-5} mc/liter mentioned above is 12 times tolerance for continuous occupational exposure, as specified in Handbook 52. However, the meteorological conditions that lead to this concentration are expected to occur at a maximum of 2½% of the time. Since it is anticipated that air-cooled experiments at high power level will be running only half of the operating time or less, these A^{41} concentrations will occur approximately 1% of the total time. Therefore these momentarily high concentrations will be acceptable.

Hazard from fuel-element failure. One can estimate the hazard from failure of a fuel element in a gas-cooled experiment releasing both particulate and gaseous fission products at a time when there is a wind blowing from the southeast quadrant. Particulate matter would be caught in the filter but gaseous products such as xenon and iodine would be emitted by the stack. It was assumed in computing the hazard from this source that during an incident 1% of a fuel element in a gas-cooled experiment operating at 6.5 Mw would fuse off and be carried out of the reactor by the coolant stream to the filter. Further, it was assumed that all of the iodine would be volatile. The latter assumption is probably conservative since at least some of the fission-product iodine undoubtedly will be bound with either the uranium fuel or with other fission products.

Should a fuel element fail in a gas-cooled experiment during normal atmospheric conditions, it has been computed that no overexposure will be incurred by persons in either the ETR-MTR area or other nearby occupied areas. However, during infrequently occurring fumigation or looping conditions, it would be possible for a person in the ETR-MTR area to receive a "technical overexposure" (dose to the thyroid greater than 25 r) from I^{131}. This exposure is approximately equal to that received from the usual tracer dose of I^{131} given for diagnostic purposes.

Under less frequent conditions such as fumigation, it also appears that an overexposure could possibly result from whole-body irradiation due to gaseous fission products in exhaust air. As a result, during those periods when a gas-cooled experiment is being operated and these adverse atmospheric conditions prevail, special precautions will be taken in the operation of the reactor, or the experiment will be discontinued until the conditions become more favorable.

COSTS

An over-all list of ETR costs is shown in the box on the opening page of this article. In Table 2 is a list of major components and the bids and delivery dates that were obtained for them.

Others have stated many times that the high estimates of cost projected for nuclear test reactors and power plants were based on the lack of familiarity with what manufacturers would charge for their components. Presumably, with no startling innovations and little developmental work, the vendor bids on ETR should have been reasonably close. Table 2 shows plainly that many of the big-ticket items still vary in cost by considerable amounts.

The advantage of using an architect-engineer as prime contractor for design and construction is quite clear: Such a firm can design and construct the most economical over-all facility without being tied to the products of any one manufacturer. It is also interesting to note that the reactor, the controls and instrumentation represent less than 20% of the over-all cost of the ETR.

* * *

Several of my associates have been most helpful in accumulating the information for this article. I would like to acknowledge the contributions of A. T. Chute, W. J. Dodson, E. A. Dukleth, J. Ernst, J. Finke, S. Kulp, A. L. Lindsay, W. M. Malott, J. Raphael, T. E. Stephens, W. Sybert, and H. D. Young.

BIBLIOGRAPHY

1. P. Mittelman, R. Liedtke, NUCLEONICS **13**, No. 5, 50 (1955)
2. S. Moyer, V. Hansen, *Trans. Am. Soc. Civil Engrs.* **120**, 1186 (1955)

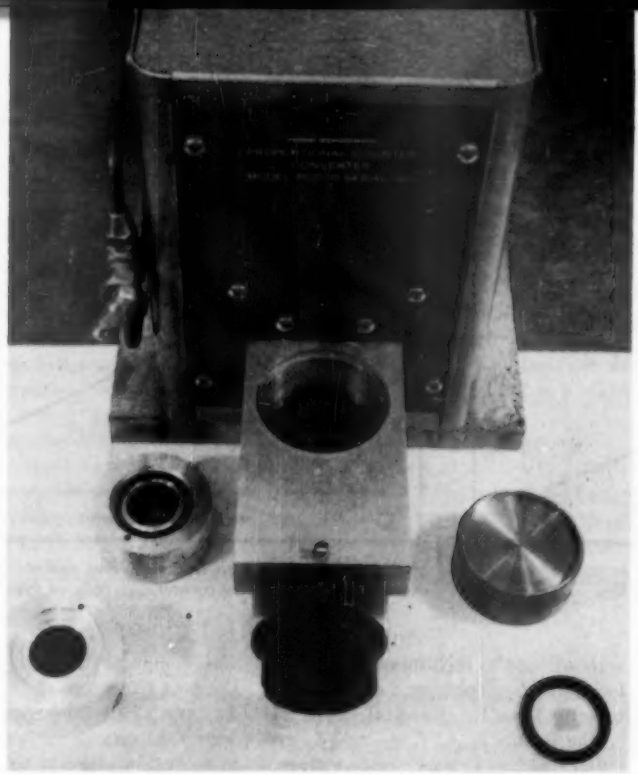


FIG. 1. 2π proportional flow counter. At bottom right is 1-cm² indium foil evaporated on collodion supporting film and mounted on graphite rings

Measuring Flux Absolutely with Indium Foils

Absolute beta counting of weighed indium foils with a 2π flow counter is advanced for measuring absolute thermal neutron flux in a reactor. This would supplant measurement relative to a standard neutron source by the usual end-window Geiger-Mueller counter method

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NEUTRON FLUXES are often measured by means of the induced beta activity of indium foils. One method is to use a combination of indium foil and counter that has been calibrated with the neutron flux from a known neutron source or standard pile.

An alternative method, described here, is to determine the absolute disintegration rate of an activated indium foil and, with the known thermal-neutron-absorption cross section of In^{115}, to compute the thermal flux. For measuring the foil beta activity we used a 2π proportional flow counter (Fig. 1) since it is most suitable for absolute measurement.

Methods

The use of indium as a detector depends on the reaction

$$In^{115} + n \rightarrow In^{116} \rightarrow Sn^{116} + e^-$$

Indium-116 has two periods, one 13 sec and the other 54.3 min. Both periods are excited by both thermal and epithermal neutrons. After the foil is irradiated in the position of interest at a constant flux for a known period of time, the 54.3-min activity is measured

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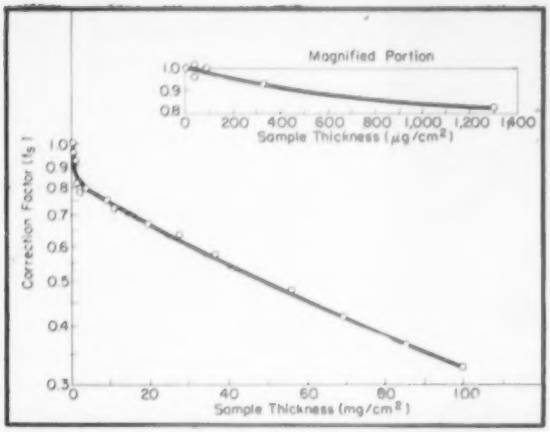

FIG. 2. Self-absorption correction factor for 2π counter without backscattering material other than supporting film

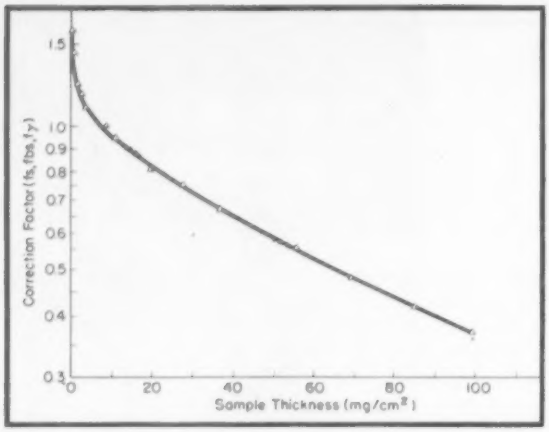

FIG. 3. Self-absorption, backscattering, and photon-contribution correction factor for 2π counter with foils on thick silver backing

after waiting several minutes to eliminate the short-lived activity. The thermal flux is

$$\phi_{th} \simeq \frac{10^3 AQ}{1.011 \times 60\sigma_0 NK(1 - e^{-\lambda t})} \quad (1)$$

The numbers 10^3 and 60 are conversion factors, for mg to gm and minutes to seconds, to express ϕ_{th} in n/cm²/sec. The factor 1.011 is a correction to take into account the Maxwellian distribution of thermal neutrons, as well as the dependence of σ on the neutron energy (*1*).

The absolute disintegration rate, Q, may be expressed in terms of the observed counting rate as

$$Q = \frac{A_{th}(x)}{f_g f_w f_e f_\gamma f_{bs} f_s(x)} \quad (2)$$

The thermal activity per mg, $A_{th}(x)$, is obtained from the measured activity, $A(x)$, by correcting for the fraction of the total activity due to thermal neutrons by measuring cadmium ratios.† An additional correction is necessary to account for the flux depression at the foil (*2*, *3*) (see columns 4 and 5 of the table). Thus $A_{th}(x) = A(x)R(x)/\alpha(x)$.

The factors f_g, f_w, f_e, f_γ, and f_{bs} are either constant or vary slowly with foil thickness. Though many workers have given calculated and experimental factors for various effects (*4–6*), no data have been found in the literature that would be directly applicable to indium. In general, such data may not be applicable unless the true disintegration energy and decay scheme of the isotope are known. The quantity that varies strongly as a function of foil thickness is $f_s(x)$, the factor for self-absorption and self-scatter in the foil. Thus

$$Qf_g f_s(x) = \frac{A_{th}(x)}{f_w f_e f_\gamma f_{bs}} \quad (3)$$

The method we used is to measure and compute the right-hand side of Eq. 3 as a function of foil thickness x. At very small thicknesses (<30 $\mu g/cm^2$), $f_s(x)$ may be assumed to be equal to unity. A graph of $Qf_g f_s(x)$ is made and extrapolated to its value of Qf_g at $x = 0$ mg/cm² and $f_s(0) = 1$. Then $f_s(x)$ is obtained by dividing each value of the $Qf_g f_s(x)$ by Qf_g. A value of Q may be obtained by measuring f_g.

† The cadmium ratio is the ratio of induced activity in bare indium foil (epithermal + thermal neutrons) to that in cadmium-covered indium (essentially thermal neutrons).

Effect of Counting Geometry

The end-window G-M counter usually employed for measurement of absolute beta activity discriminates against the low-energy portion of the direct and scattered components of the beta-ray spectrum.

Now the angular distribution of beta particles emitted by an isotope varies markedly with sample thickness (*6–8*) —thin samples emit betas isotropically, but thicker samples cause the angular distribution of the electrons to approximate a cosine function, i.e., there is a preferential forward distribution.

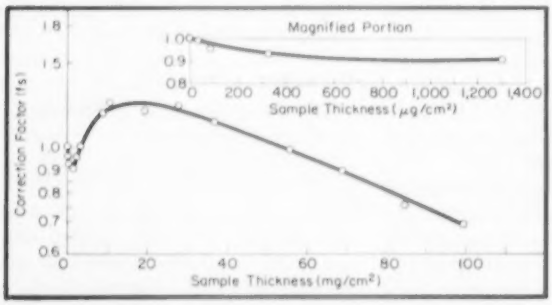

FIG. 4. Self-absorption correction factor for end-window G-M counter at 2.2 cm from backless foils. Minimum is due to soft-beta self-absorption

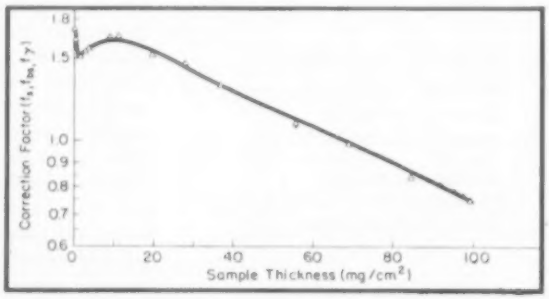

FIG. 5. Self-absorption, backscattering, and photon-contribution correction factor for G-M counter at 2.2 cm from foils on thick silver backing

Symbols Used in Calculations

ϕ_{th} = standard thermal-neutron flux, $n_0 v_0$ (n/cm²/sec)

n_0 = thermal-neutron density at standard energy E_0 = 0.025 ev (n/cm³)

v_0 = standard velocity of 2.2×10^5 cm/sec, corresponding to standard energy

A = atomic weight of In^{115} = 115 gm

σ_0 = microscopic thermal absorption cross section for In^{115} at the standard energy E_0 for producing 54.3-min period = 145 ± 21 barns (*12*)

N = Avogadro's number = 0.602×10^{24} atoms/mole

K = fractional abundance of In^{115} = 0.9577

Q = absolute disintegration rate per mg due to thermal neutrons

λ = disintegration constant for 54.3-min period = 0.01276/min

t = irradiation time (min)

$A_{th}(x)$ = thermal activity/mg in counts/mg/min at moment of withdrawal from reactor

x = foil thickness (mg/cm²)

f = correction factors, relating disintegration rate to activity, for geometry, window absorption, efficiency, gamma background, backscatter of mounting material, self-absorption, and self-scatter of indium foil for emitted beta particles

$R(x)$ = fraction of total specific activity due to thermal neutrons

$A(x)$ = total specific activity

$\alpha(x)$ = thermal-neutron self-shielding correction factor (relative activation per unit mass)

In the case of a counter subtending a very small solid angle about the normal to a thick specimen, the observed activity per unit solid angle will be twice the average obtained by measuring over all angles. This phenomenon may prevent one from extrapolating self-absorption data to zero thickness of sample unless rather complete absorption data are obtained from nearly weightless specimens.

2π geometry. If self-absorption curves are obtained with a 2π-geometry detector, the angular-distribution variations for different sample thicknesses will not affect the counting rate. Also a 2π counting geometry has a higher counting yield as compared with background. For these reasons, a windowless proportional counter with a 2π geometry, for which $f_s = f_w = 1$, was used as the detector in these experiments.

Counters

The detector we used is a modified Nuclear Measurement Corp. proportional counter converter Model PCC-10 (*9*). It is a flow counter using an argon-methane mixture at atmospheric pressure. The modification was a hollow aluminum cylinder to support the indium-foil assembly (Fig. 1). This permitted making measurements with and without a backscattering material. Sufficient space was provided between the indium foil and the surrounding structure to eliminate all backscattering except that from the film supporting the indium.

Since most past measurements of beta activities have been made with end-window G-M detectors, it was decided to make a series of measurements comparing the two types of detectors. A standard G-M counter, Tracerlab's TGC-2, with a 1.9-mg/cm² mica end window was used. Samples were placed on the second shelf, 2.2 cm from the window. To perform the backless counting with the detector, a special aluminum support was used to hold the irradiated sample.

Foil Preparation

All foils used were commercially pure (99.97%) indium, 1.0 cm × 1.0 cm, and with thicknesses of 30 μg/cm² to 100 mg/cm². From 20 mg/cm² to 100 mg/cm², rolled foil material was used. Indium foils of 15 mg/cm² or less were evaporated on supporting films. The foils in the range 1 mg/cm² to 100 mg/cm² were supported by Formvar films mounted on thin aluminum rings. The Formvar films varied in thickness from 2.6 to 3.4 mg/cm². For the very thinnest indium foils (30 μg/cm² to 1 mg/cm²) the indium was evaporated on thin collodion films (*10*) whose thickness was approximately 50 μg/cm². In one case the thin foil was prepared by evaporation on 0.5-mg/cm² Pliofilm.

All supporting films were mounted on 1.5-in.-diameter graphite rings (Fig. 1). Graphite was chosen because of its low scattering cross section for In^{116} betas and because of its suitability for placement in the graphite moderator of the water-boiler reactor used for the irradiation. Additionally, the graphite used is sufficiently pure so that no induced long-lived contaminant activities interfered with the beta counting.

All the foils were weighed to determine their thicknesses. For the evaporated foils down to 1 mg/cm² the thickness was determined by weighing the assembly both before and after the evaporation of the indium. For the very thinnest indium foils the thicknesses were determined both by difference weighing and by the following spectrochemical technique: The indium is dissolved in a known volume of HCl. A portion of the sample solution is placed in a flame photometer, and the intensity of an indium emission line compared with the intensity of the same line emitted by calibrated solutions of indium in HCl. This method permits the determination of thicknesses to within 2%.

Experimental Results

The indium was activated by placing it in one of the graphite stringers in the reflector of a low-power water-boiler reactor. The activated foils were counted alternately in the 2π proportional counter and in the G-M detector with and without a thick silver backing.

Sufficient counts were taken to ensure good statistical accuracy. Dead-time corrections were made for the count in the G-M detector, but none were necessary for the 2π detector.

Appropriate corrections were made for the backscattering effects of the film supports. The table gives the experimental data obtained for the 2π detector with no backscatterer. For completeness this table includes the total measured activity of a foil with the stated weight, the cadmium ratio (see

col. 3), and the correction factors, $R(x)$ —the fraction of $A(x)$ due to thermal neutrons, $\alpha(x)$—correction for self-shielding of the foil to activation by thermal neutrons. The last column gives the correction factors for self-absorption and self-shielding effects.

The curves of Figs. 2 and 3 are based on data obtained with the 2π proportional counter. The data in Figs. 4 and 5 were obtained in the end-window G-M counter with the sample always placed on shelf 2 (2.2 cm from the window).

Correction for photons. A relatively small fraction of all counts in both types of detectors were due to gamma and X-rays emitted by the activated indium atoms. The correction factor for this effect, f_γ, was obtained by means of absorption curves, and the results for the 2π detector are given in the table.

For the G-M detector the counts due to the photons were about 3% of the total count. For the proportional counter the range was 2–6% going from the thinnest to the thickest foils. Figures 2 and 4 have been corrected for the contributions of photons. Thus, these data reflect counts due to betas only. Figures 3 and 5, obtained with thick silver backing, have not been corrected for photon counts. This was done to simplify the procedure for other workers for making corrections to their total counts, so that the absolute counting rates of indium foils could be obtained by dividing observed counting rates by the ordinates of these curves.

Discussion

The curves of Fig. 2 have the expected shape for a beta emitter having two or more continuous beta spectra. The preferential forward scattering with increased sample thickness has no effect on the count since geometry is 2π. Thus one observes only the effect of self-absorption, which increases with the sample thickness. As is the case for an ordinary absorption analysis of a mixture of beta spectra, the initial steep portion of the semilog plot arises mainly from the absorption of the lower-energy component. The remaining portion arises from the absorption of the higher-energy components.

In the case of In^{116}, there are three known beta spectra with estimated maximum energies of 0.6, 0.87, and 1.0 Mev with relative intensities of 21, 28, and 51%, respectively (*11*). Of the total beta radiation, 6% deviates above the straight Fermi line at energies less than 250 kev, indicating the presence of a lower-energy component.

By contrast, Fig. 4 gives the self-absorption and self-scattering factor for indium, with no backing, obtained with a thin-window G-M detector. It exhibits the same characteristics as does Fig. 2, but with one added feature. In a narrow-geometry detector, as was used here, there is the additional effect of increasing preferential scattering in the forward direction with increasing sample thickness. This produces the minimum (at about 1 mg/cm² of sample) and the maximum (at about 12 mg/cm² of sample) shown in Fig. 4. The first portion (less than 1 mg/cm²) of Fig. 4 is due to self-absorption of the soft-beta spectrum. As the sample thickness increases, the preferential forward scattering tends to increase the count. The balancing of these two effects produces the minimum.

Further increases in sample thickness cause an actual increase in counts due to the increased effect of the preferential forward scattering. However, the absorption of the more energetic components of the beta spectra becomes important also. The balancing of these latter two effects produces the maximum.

The maximum in Fig. 4, 1.24, occurs for 12–18 mg/cm². This maximum is in good agreement with results reported (*6*) for Pr^{143}, whose beta, $E_{max} = 0.92$ Mev, corresponds to the average of the betas from In^{116}.

Effect of forward scattering. It has been shown (*7*) that the increased forward scattering with a thick sample into a narrow-geometry detector re-

Thermal-Neutron Measurements with 2π Detector and No Backscatterer

Indium weight (mg/cm²)	$A(x)$	*Cadmium ratio*	$R(x)$	$\alpha(x)$	$A_{In}(x)$	f_γ	f_{o_s}	Qf_sf_s	$f_s(x)$
0		2.385	0.5609	1.00				6,523*	1
0.0346	12,149	2.385	0.5609	1.00	6,814	1.019	1.008	6,630	1.016
0.0367	11,435	2.385	0.5609	1.00	6,414	1.019	1.008	6,241	0.957
0.0827	11,801	2.405	0.5646	1.00	6,664	1.020	1.008	6,477	0.993
0.325	10,926	2.445	0.5718	1.00	1,246	1.021	1.019	6,000	0.920
1.30	9,582	2.57	0.5926	0.996	5,701	1.023	1.040	5,356	0.821
2.1	8,833	2.72	0.6153	0.993	5,580	1.024	1.036	5,257	0.806
3.074	8,644	2.80	0.6263	0.990	5,468	1.026	1.030	5,173	0.793
8.86	7,114	3.42	0.6944	0.975	5,067	1.030	1.001	4,915	0.753
10.819	6,621	3.60	0.7098	0.9686	4,852	1.031	1.000	4,705	0.721
19.384	5,631	4.30	0.7574	0.951	4,484	1.035	1.000	4,333	0.664
27.408	5,076	4.89	0.7869	0.936	4,267	1.038	1.000	4,109	0.630
36.558	4,451	5.40	0.8073	0.922	3,897	1.042	1.000	3,738	0.573
55.492	3,528	5.98	0.8261	0.895	3,256	1.043	1.000	3,121	0.478
69.014	3,051	6.16	0.8312	0.877	2,890	1.054	1.000	2,743	0.420
85.06	2,594	6.25	0.8337	0.858	2,520	1.058	1.000	2,381	0.365
99.58	2,304	6.27	0.8342	0.840	2,287	1.061	1.000	2,154	0.330

*Obtained by extrapolation of Qf_sf_s to its value of Qf_s at $x = 0$ mg/cm².

sults in recording an activity per unit solid angle that is twice that which would be observed if the detector counted an average over all angles.

To check this point the curve shown in Fig. 6 was computed. As Fig. 6 indicates, the ratio of small-geometry activity ($\ll 2\pi$) to that of the 2π geometry varies from unity at small thicknesses (no preferential scattering) to approximately 2.1 at the greater foil thicknesses. The 5% deviation from 2.0 is within the limits of the estimated experimental error.

Further evidence to support the explanation of the shape of the curves in Figs. 2 and 4 is the fact that the initial slopes are very nearly the same; e.g., at 325 $\mu g/cm^2$ of sample, both curves are down to about 92% of the initial value (see magnified portions of these figures). The same self-absorption is occurring in both samples in the two detectors; however, the additional phenomenon of preferential forward scattering in a narrow-geometry detector is not important for sample thicknesses of indium less than ½ mg/cm^2. Thus, one would expect the same absorption curves for both detectors for these extremely thin samples.

Effect of window thickness. One may obtain quite complex self-absorption curves when a narrow-geometry G-M detector is used. In the present case, the use of a relatively thin window (1.9 mg/cm^2) and an air-absorption path of 2.5 mg/cm^2 permitted this initial soft-component absorption to be observed.

Had the G-M window been 3–5 mg/cm^2 thick, the energy cutoff would have been such that the initial portion of Fig. 4 would not have been detected. Instead one would have observed a curve similar to those reported in the literature with only a maximum.

For a beta emitter with a single beta spectrum, of relatively high energy, this effect of the air-window thickness is not critical. On the other hand if the spectra are multiple in nature and contain appreciable percentages of low-energy components, very thin air-window thicknesses are necessary to obtain useful self-absorption curves.

Because of these complexities it is better to employ 2π or 4π detectors with thin or no windows.

Correction factors. Figures 3 and 5 were obtained with thick silver backing. The backscattering factor for an infinitely thin sample is approximately 1.67 for the narrow-geometry detector. This value of the backscattering factor for silver is consistent with values quoted in the literature for comparable circumstances. The backscattering factor for the 2π counter with similar sample conditions is 1.63. These backscatter factors for silver have been corrected for photon counts.

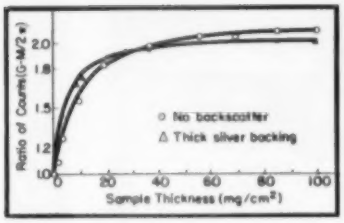

FIG. 6. Magnitude of forward scattering with narrow-geometry counter, expressed as ratio of narrow-geometry counts to 2π counts

As the sample thickness increases, one would expect the backscattering factor to approach unity for all detectors. The ratios of Figs. 2 and 3 and of Figs. 4 and 5 show backscattering factors of about 1.04 for both detectors at a sample thickness of 100 mg/cm^2, both corrected for the photon effect.

The correction to be applied to a 100-mg/cm^2 foil to compensate for the effect of self-absorption is almost 3 in 2π geometry. The self-scattering and self-absorption correction for a 100-mg/cm^2 foil counted in a G-M detector with 7% geometry is approximately 1.4. In practical applications when an infinite silver backing is used for supporting the foils, the corresponding correction factors are 2.7 and 1.3.

Estimated errors. The estimated errors that affect the accuracy of the curves in Figs. 2–5 include the following:

1. Foil weights, estimated error $\leq 2\%$.
2. Counting error, estimated $\leq 3\%$.
3. Errors in estimating counts due to backscattering of supporting film, gamma rays, neutron self-shielding, $<3\%$.
4. Errors in cadmium ratio, estimated $\leq 1.5\%$.

The estimate of total error based on the above is approximately 5%, computed as the square root of the sum of squares of the individual errors.

Computed Thermal Flux

The value of Qf_g obtained with either of the two types of detectors may be combined with measured f_g to yield a value for Q for the conditions of our experiment. This was done with the following results

$$Qf_g = 6{,}523 \text{ cpm/mg}$$
$$f_g = 0.49 \ (\sim 2\pi)$$
Thus $$Q = 13{,}312 \text{ dpm/mg}$$

Equation 1 may be used to compute ϕ_{th}. Using the values of the parameters quoted in this article to compute the thermal flux at 100 milliwatts at the position of measurement for an average exposure time $t = 7.4$ min

$$\phi_{th} = 3.17 \times 10^6 \text{ n/cm}^2\text{/sec}$$

There are two sources of error in this computation of ϕ_{th}. One is the uncertainty in Q discussed in the preceding section. The second and major source of uncertainty is in the value of In^{115} absorption cross section σ_0, which has a standard deviation of 15% of the mean (*12*) from measurements of irradiated indium foils.

Seren et al. made a correction, based on external absorption measurements, for self-absorption by the foil on a simple exponential basis. The shape of the curves reported here show that (a) the correction factor is non-monotonic with both a minimum and a maximum in the low-geometry case; (b) the self-absorption and self-scattering correction is not linear in a semilog plot for even the 2π geometry. In fact, for foil thicknesses up to 20 mg/cm^2 the correction may be either positive or negative, depending on the foil thickness. Thus the reported value of σ_0 may be in error because of the impossibility of using a simple exponential type of correction for this complex phenomenon.

* * *

This work was done under the auspices of the U. S. AEC on contract AT 11-1-GEN.

BIBLIOGRAPHY

1. Neutron Cross Sections, BNL-325 (1955)
2. R. L. Koontz, M. A. Greenfield, A. A. Jarrett, NAA-SR-1137, Part II
3. W. Von Bothe, *Zeit. f. Physik* **120**, 437 (1943)
4. L. R. Zumwalt, AECU-567 (1950)
5. Nuclear Science Series, Conference on Absolute Beta Counting, Preliminary Report No. 8 (1950)
6. W. E. Nervik, P. C. Stevenson, NUCLEONICS **10**, No. 3, 18 (1952)
7. R. G. Baker, L. Katz, NUCLEONICS **11**, No. 2, 14 (1953)
8. C. H. Collie, *et al.*, *Proc. Phys. Soc. (London)* **A63**, 282 (1950)
9. NUCLEONICS **6**, No. 4, 87 (1950)
10. S. D. Warshaw, S. K. Allison, *Revs. Mod. Phys.* **25**, 780 (1953)
11. H. Slatis, S. J. duToit *et al.*, *Phys. Rev.* **78**, 498 1950
12. L. Seren *et al.*, *Phys. Rev.* **72**, 888 (1947)

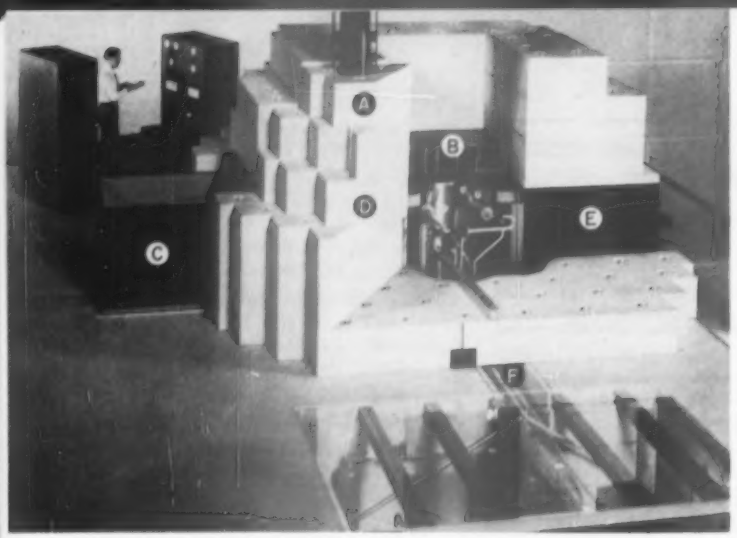

FIG. 1. Model of completed reactor shows light-concrete shielding *A*, *D*, heavy-concrete shield above core *B*, shield-test facility *C*, core, thermal column *E*, and lines leading to dump and storage tank *F*

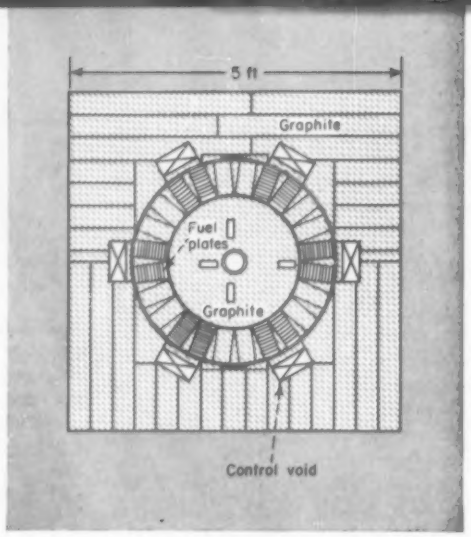

FIG. 2. Reactor configuration consists of external and internal graphite reflectors and annular core containing fuel, graphite, and water

Argonaut—Argonne's Reactor

Annular core provides greatest flexibility for experimenters. Dump system and gas sparge increase the safety of this reactor, which is inherently safe due to its temperature characteristics

By R. H. ARMSTRONG and C. N. KELBER *Argonne National Laboratory, Lemont, Illinois*

INSTRUCTION AND RESEARCH in reactor physics involve studies of (a) spatial, temporal, and energetic distributions of neutrons in chain-reacting systems and (b) the interactions of neutrons with matter. For studies of the first kind the usual high-flux research reactor is not suitable. It is generally encumbered with massive heat-removal systems and permanent experimental ports that preclude use of the reactor as a measuring instrument or a flexible demonstration assembly.

On the other hand, zero-power reactors have proved to be vital facilities for experiments pertaining not only to design problems, but also to general problems in reactor physics. They have also been, almost without notice, the most effective instruments for training reactor physicists. It is important that the distinctions just made be considered, since there are fundamental differences in application between high-flux and low-flux reactors, even when cost is not considered.

In designing a system for university application in reactor physics, ease and safety of operation, versatility, and economy of construction have been considered paramount. The primary criteria for choosing among competitive systems are that an experiment performed by a student must yield results that are reasonably accurate if the student has done his work reasonably well, and that a student wishing to do original work should not be thwarted by an inflexible reactor.

The major requirement of an experiment is that it be sensitive to changes in the parameter examined and insensitive to changes in other quantities. In this respect a reactor is not usually an ideal system, since it is almost indiscriminately sensitive. Nevertheless a reactor with an annular geometry offers, inside the annulus, an ideal spot for testing components. Such a geometry is also excellent for conducting internal exponential experiments—a technique that promises much in the way of aid and comfort for the reactor engineer.

More on School Reactors

- **Two firms to sell Argonauts. Nucleonics 15, No. 1, R8 (1957)**
- **A. T. Biehl, et al. Compact, low-cost reactor emphasizes safety. Nucleonics 14, No. 9, 100 (1956)**
- **Small 5-watt reactor is for teaching, research. Nucleonics 14, No. 10, 98 (1956)**

Over-All Description

Argonaut is a thermal, heterogeneous, and water-cooled reactor. The design is based on an MTR-type loading of an annular core reflected internally and externally by graphite. Safety is inherent in the core type by virtue of the temperature characteristics. Additional safety has been introduced by several design features. In unrestricted locations the reactor will operate safely at powers up to 10 kw and thermal-neutron fluxes up to $\sim 10^{11}$ n/cm²/sec. A reliable cost esti-

TABLE 1—Characteristics of the Argonaut

Maximum power	10 kw
Maximum thermal flux	10^{11} n/cm²/sec
Critical mass	3.7 kg of U (20% enriched)
Type of core	Annular, heterogeneous
Core size	36 in. o.d., 24 in. i.d., 24 in. high
Moderator	90 gal H_2O + 476 lb graphite
Internal reflector (graphite)	24 in. diam × 46 in. high
External reflector (graphite)	62 in. square × 48 in. high
Main shield	72 in. ordinary concrete (150 lb/ft³)
Shield over lattice	12 in. barytes concrete (220 lb/ft³)
Over-all width (across flats of hexagon)	17 ft
Over-all height	~7 ft
Temperature coefficient of reactivity	-1.065×10^{-4}/° C
Water circulation rate (max)	~6.5 gpm
Storage-tank volume	275 gal
Utility requirements	
Electricity	40 kw, 110-v a-c, single phase
Water	2 gpm, 75° F

TABLE 2—What Does It Cost?

Building additions	$ 9,041
Graphite	26,771
Startup source (Sb-Be)	250
Heat exchanger	175
Pump	135
General piping, valves, tank	3,594
Reactor vessels	1,359
Shielding	4,845
Control units	1,876
Structure	1,953
Fuel assemblies	2,830
Shield-test facility	1,200
Electronics and instruments	15,000
Loading mechanisms	5,650
Miscellaneous	2,011
Total	$76,690
Argonaut building, slab, and foundation	$20,670

for University Training

mate including building is $100,000. Table 1 lists the essential characteristics. Figure 1 shows a model of the reactor, and Table 2 is a cost breakdown.

An annular geometry offers more volume in which to conduct experiments than other types. This is at the cost of a large critical mass since the shape is fundamentally a leaky one. However, since 20%-enriched uranium is being released in generous quantities for research purposes, it is felt that critical mass is important only in the way it affects safety and operation, not as a prime consideration.

The design has been developed on a do-it-yourself philosophy. It requires a minimum of skilled personnel for erection and tryout. Low cost figures result from designing wherever possible to use standard, off-the-shelf items. Basic design of Argonaut stemmed from the KAPL TTR, now NTR (*1*).

Mechanical Design

The Argonaut assembly is a graphite cube with a central annular core. The annulus is formed by two concentric aluminum tanks. In its center is a cylindrical graphite reflector that can be removed and replaced by a portion of a lattice assembly for internal exponential experiments. The top of the reactor is kept free of mechanisms so as to be accessible for loading fuel assemblies, insertion of experiments in the central reflector, and possible installation of external subcritical assemblies.

A total of 22 experimental ports are available. Five are in the central reflector as shown in Fig. 2. Against one face of the graphite cube is a graphite thermal column 5 ft wide, 5 ft long, and 4 ft high (Fig. 1). This has 15 horizontal experimental ports. Ordinary concrete blocks are stacked against the two adjacent faces, each of which has one experimental port.

Opposite the thermal column is a mobile flat-bed truck, on which is mounted a removable water tank that is 4 ft wide, 6 ft long, and 3½ ft high. It is designed for shielding studies with an aqueous medium. When it is removed, solid materials can be stacked on the truck bed for testing. A hand jack is provided to move the truck toward the lattice and away.

Core

The core annulus contains fuel elements, graphite, and water. The 204 fuel plates are arranged in 12 clusters of 17 plates per cluster. Moderation is provided by graphite segments between clusters and water between fuel plates in each cluster. The graphite segments—waterproofed with Krylon aluminum paint—are hung with aluminum mounting brackets from the edge of the aluminum outer reactor vessel.

Fuel plates are as shown in Fig. 3. They are made of 20%-enriched U_3O_8 suspended in an aluminum matrix. By the use of a box jig they are easily assembled in clusters and secured by aluminum screws.

An antimony-beryllium source provides neutrons for startup. It consists of an antimony plug in a beryllium cube that is moved into the reflector zone by an electric drive when it is to be used. It produces 10^8 neutrons/sec.

Water System

A water-circulation system serves for heat removal and also, by means of a quick-dump arrangement and a gas sparge, for safety shutdown.

Figure 4 is a water-system diagram, and Fig. 1 shows location of the pipes. Tap water flows into a 5-gal/hr laboratory mixed-bed ion exchanger and then to the aluminum dump tank to supply cooling water for the reactor. This cooling water flows through the tube section of the heat exchanger. A separate circuit provides cooling water for the shell of the heat exchanger. Flow rate through the shell is controlled by a solenoid valve actuated by thermal switches in the reactor outlet line.

Only about 125 gal of makeup water

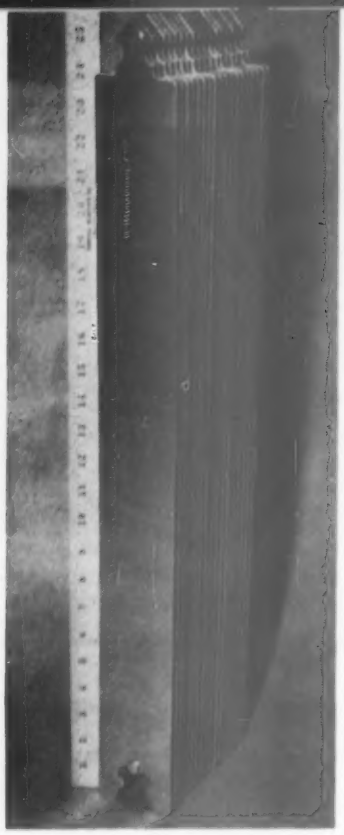

FIG. 3. Fuel assembly is cluster of 17 aluminum plates with dispersed U_3O_8

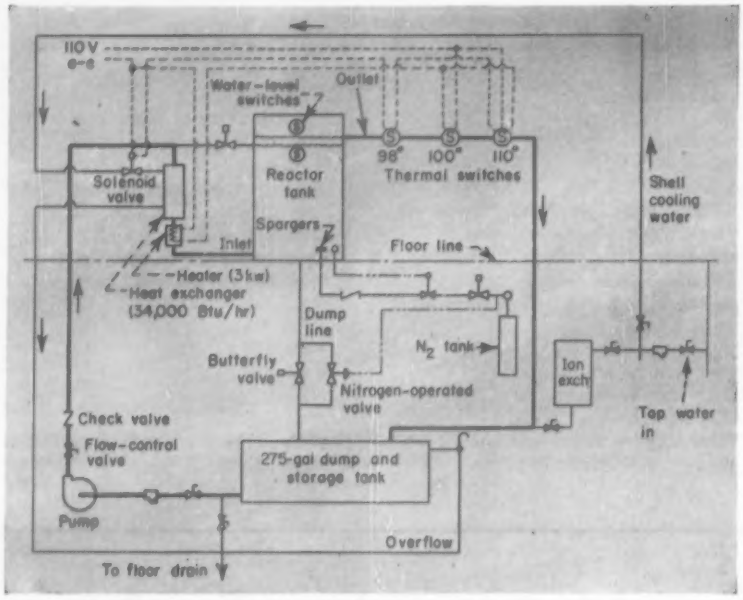

FIG. 4. Flow diagram of water and gas-sparging system

is necessary to operate the reactor when graphite is used in the center of the annulus. Extra tank capacity is available in case the experimenter wants to remove the central graphite column and the inner aluminum tank and substitute an entirely different core of his own design.

The tank has an overflow line and an opening in the top for insertion of apparatus when this is desired. Its outlet feeds through a strainer into the suction side of a ¼-hp stainless-steel centrifugal pump* rated at 20 gpm against a 14-ft head. Discharge of the pump is connected through an adjustable flow-control valve and a check valve to the tube side of a stainless-steel shell-and-tube heat exchanger† with 4.3 ft² of surface. From the heat exchanger the stream passes through a heater to the inlet of the reactor tank. The heater provides moderator-temperature control. It is energized by a series of thermal switches and a snap-action controller in the reactor outlet line.

Coolant is pumped upward through the reactor, over a weir, and back into the main dump tank. Its level is monitored by two safety float switches, one to indicate when the water has reached the operating level and one to stop the pump if the level becomes too high.

Cooling by natural convection is possible at low power. The normally closed solenoid valve between tank and heat exchanger opens, dropping the water level and permitting circulation through the shorter circuit.

Emergency shutdown. Two completely independent systems are provided for emergency shutdowns. A dump line empties the coolant-moderator into the dump tank. Simultaneously a nitrogen sparging system introduces bubbles to reduce moderator density.

Welded to the bottom of the main reactor tank is a 6-in. aluminum dump line that leads to the dump-and-storage tank. The line passes through a 6-in. rubber-lined, electrically operated butterfly valve that is normally held closed by a magnetic clutch. If the clutch is de-energized, a weighted lever arm opens the valve and empties the water into the dump tank. Torque required to open the valve is ~78 in.-lb.

The supplementary safety system introduces nitrogen through a series of 35-micron porosity spargers. The gas passes through a quick-opening valve to produce a rapid decrease of moderator density. The gas system is made fail-safe by using the nitrogen pressure to hold closed a 1-in. moderator drain.

Shielding

The area directly above the cubic lattice is shielded by a 5 × 5 × 1-ft concrete-filled steel box. A 3-ft-diameter stepped plug is located directly over the core, and in this plug are smaller plugs for the insertion of fuel assemblies and test materials into the central column. All plugs contain heavy concrete. In high-power experiments additional bricks of ordinary concrete will supplement the heavy-concrete shield as shown in Fig. 1. For moving shielding components a 3-ton jib crane with a 15-ft boom arc is provided.

Shielding above the lattice and the mobile truck is supported by a structural assembly made by bolting together 6-in. flanged aluminum beams. In addition a 5-ft × 5-ft × ½-in. aluminum plate is bolted over the lattice, and several 6 × 6-in. wooden beams are laid side by side above the shield-test tank. These pieces form an adequate structure that can be dismantled and reassembled with simple tools if it is desirable to move or modify

* Eastern Industries Model WA.

† Ross Heater Div., American Standard, no. 301-2, 34,000-Btu/hr rating.

the reactor. On the 4 inner columns the loading is 10,000 lb/column, and on the 2 outer ones it is 4,700 lb/column. Maximum bending stress on the horizontal beams is 7,000 psi. Aside from the column loads the floor loading is 1,500 lb/ft².

Instrumentation

The reactor is operated from a console that contains the following standard instrumentation: 2 strip-chart recorders; 1 logarithmic-amplifier period and power trip; 2 d-c linear-amplifier high-level trips; 2 counting channels, one with rate meter, both with scalers, linear amplifiers, and pulse-height discriminators; 2 area gamma monitors; 1 master rotary switch for startup.

Because the reactor is inherently safe, the major control problem has been to design cheap, effective secondary control mechanisms. This is complicated by our desire to leave the top face free for external subcritical assemblies. Several satisfactory control systems were proposed and tested before a final selection was made.

The control system currently used is a mechanism consisting of a small rotary solenoid operating through a magnetic clutch and brake to a steel cable. The cable moves a 7 × 7-in. plate assembly that contains cadmium as poison.

For a training reactor a startup pattern that does not require unusual skill or lengthy training for mastery is highly desirable. For Argonaut a sequential system of interlocks has been designed so that the operator must bring the reactor to critical in a specified manner. Each operation is controlled through one central selector switch. If a step is omitted, or an interlock not satisfied, the operator cannot go on to the next step. The rotary startup switch passes to the following 9 positions in the order listed: source, safety rod 1, safety rod 2, safety rod 3, dump valve, water level, shim rod, coarse control rod, fine control rod.

Safety

In addition to the previously discussed safety features that have been built into the water system, Argonaut has inherent safety in the temperature characteristics of its core. The group of such inherently safe reactors includes the Materials Testing Reactor and Borax at Arco and the Low-Intensity Testing Reactor and the Bulk-Shield Test Facility at Oak Ridge. Borax tests have demonstrated that in reactors of this type it is difficult to cause a nuclear runaway even when safety circuits are inoperative (*2*).

With normal reactor loadings multiple failure of safety devices could permit an excursion, but it would be terminated automatically by the increase of moderator volume and void formation, without any release of fission products to the environment.

The only dangerous situation that we can conceive would occur if a large mass of reactive material were dropped into the internal thermal column with fuel in the annulus and water up. This accident could stem only from premeditated folly, since standard procedure of unloading the annulus and dropping the water while making an internal change is enforced by multiple interlocks and made convenient by the system design. Thus, the nuclear system of Argonaut is safe if the user takes only minimal precautions against grossly unsafe practices.

Operating Personnel

Competent personnel are required to supervise Argonaut operation. Initially, of course, only people with previous training in existing installations would be competent supervisors, although such training ought to be an important phase of student activity. Experience at Argonne has been that an experimental physicist can be checked out as a pile operator after about four months' training; students working with an Argonaut can probably be trained in about four to six months depending on their skills. Further experience at the International School of Nuclear Science and Engineering should yield more information on this.

The operator or supervisor has following responsibilities:

1. Monitors, trips, and safety devices must be checked operationally for proper function. If these devices are not working properly, the responsible person must have authority to shut down the reactor until necessary repairs are made.

2. All experimental proposals must be reviewed with regard to their safety, and all experimenters must be taught safe operation.

3. Checks must be made that experiments are being safely performed.

An internal exponential experiment converts Argonaut into a much different reactor. Hence, such experiments must be subjected to a separate safeguard review unless they differ in only minor respects from previously tested systems.

Part of the safety program is the provision that the excess reactivity built into the lattice be limited, and that all fuel be under control of one responsible person. The interlock and trip circuits are of conventional design for research reactors with a few novel additions. Chief among them is a measurement of the source-flux multiplication prior to raising the shim rods for criticality. This prevents introducing too much excess reactivity into the system at the beginning of an experiment. A burglar alarm prevents personnel from working on the top of the reactor when it is operating.

* * *

This article is a compilation of work done by the Argonaut group: D. H. Lennox, project engineer, R. H. Armstrong, F. Bewersdorf, C. N. Kelber, W. H. Kolb, A. Selep, and B. I. Spinrad, with the generous assistance of the other divisions of Argonne National Laboratory. The help of Rudi Yu Tung Yang is particularly appreciated.

BIBLIOGRAPHY

1. NUCLEONICS **11**, No. 5, 38 (1953); "Research Reactors," p. 312 USAEC (McGraw-Hill Book Co., New York, 1955)
2. J. R. Dietrich in "International Conference on the Peaceful Uses of Atomic Energy," vol. 13, p. 88 (United Nations, New York, 1956)

Experiments with Argonaut

With the standard Argonaut system one can perform the following kinds of experiments:

PILE-OSCILLATOR MEASUREMENTS and danger-coefficient studies in the central column.

EXTERNAL EXPONENTIAL EXPERIMENTS on the top or side of the system (10^7 thermal neutrons/cm²/sec).

CRITICAL MASS DETERMINATIONS on the annular core with various geometries and concentrations.

FUEL STANDARDIZATIONS and instrument calibrations in the various irradiation spaces.

SHIELDING STUDIES in the shielding tank.

IRRADIATIONS of fuel elements to get internal flux distributions, etc., in the thermal column.

Krypton-85 Source Improves Industrial Thickness Gages

By W. EVERETT SWIFT
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THE USE OF KRYPTON-85 as a beta source in industrial thickness gages substantially improves the signal-to-noise ratio of these instruments. A recent survey article in NUCLEONICS (*1*) indicated that the signal-to-noise ratio was an important factor in the performance of automatic thickness control systems, but listed only strontium-90 and thallium-204 as source materials. The only published reference to the use of krypton-85 is in the English literature (*2*).

Signal-to-Noise Ratio

Figures 1–3 illustrate the improvement in signal-to-noise ratio obtained with a krypton-85 beta-gaging source. They illustrate statistical noise only, because the other noises that are independent of signal strength are difficult to demonstrate, but respond similarly. The charts are photographs of ink recordings of the output of a beta gage as variations are introduced in source and amplifier. The deflection to the right in each case is a measure of the response when an absorber, 1.6-mg/cm² plastic film, is inserted between the source and the detector.

The over-all improvement shown in Fig. 3b is due in small part to the greater absorption of the lower energy beta rays, as indicated by comparison of Figs. 2a and 2c, but in greater part to the increase in effective source strength for the krypton sources. Roughly, as measured by an ionization-chamber-type survey meter, the effective strength of a Kr^{85} source is three times the strength of a Tl^{204} source.

Although Tl^{204} sources of approximately the same strength and size as the Kr^{85} sources could have been made, it would have required material of very high specific activity, upwards of 200–300 mc/gm, which is not always available. Also, the cost of the activity would be appreciably higher.

The effective strength per unit area of thallium beta-ray sources is limited by self-absorption. With the enormously high specific activity of even the relatively dilute Kr^{85} (about 5% of the total krypton as supplied at present) very strong fields of beta rays are easily obtained.

The relatively long half-life of Kr^{85} (10 yr), compared with 4 yr for Tl^{204}, is an attractive feature to the designer of beta-gaging equipment. It not only increases the useful life of the source, saving replacement cost, but it reduces the frequency of recalibration necessary to maintain a given standard of accuracy in an instrument.

Despite its longer half-life, 25 years, the *apparent decay* of a strontium-90 source is greater than that of krypton-85. By apparent decay we mean the thickness of material in mg/cm² which by absorption would cause the same attenuation of the betas as would occur in a month by radioactive decay. This quantity is tabulated in the table. It provides a measure of error, in terms of thickness of material, introduced by radioactive decay in one month. Calculation shows that krypton-85, with a lower energy and higher absorption factor, has a lower apparent decay than the longer-lived strontium-90.

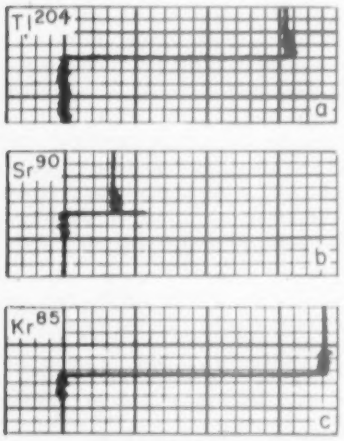

FIG. 1. Comparison of beta gage response when source strength is adjusted by an opaque shutter to give the same ionization current at no-absorber, mid-point position; 1.6-mg/cm²-absorber is inserted; amplifier sensitivity is fixed

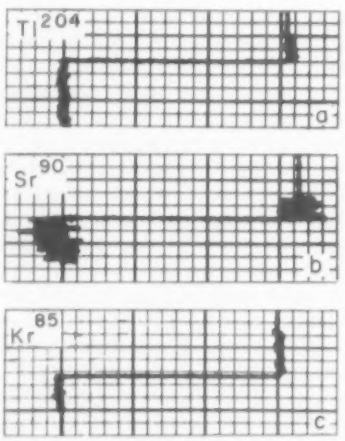

FIG. 2. Comparison of beta gage response when ionization chamber current and absorber are the same but amplification is increased for Sr^{90} and decreased for Kr^{85} to give same signal magnitude as Tl^{204}

Kr^{85} sources can be made in almost limitless variety. The only requirement is that the container be leaktight with a thin window to permit a beam of beta radiation to escape. Windows of stainless steel, nickel, monel metal or any other corrosion-resistant metal foil, 0.0005–0.002 in. thick, can be attached by seam welding, brazing or soldering, to a heavier metal cup or some type of thin-walled tubing can be used.

Because Kr^{85} is a gas it is easy to adjust source strength during the filling operation. The capsule is evacuated, a radiation measuring device is set up, krypton is allowed to bleed in until the required strength is reached, and the tubulation is pinched off and solder-sealed.

Radiation Safety

Perhaps the most attractive feature of Kr^{85} as a beta gaging source is radiation safety. Krypton is a gas at all normal temperatures. In case of a leak, the word "spill" is hardly applicable, since the gas is quickly dissipated into the atmosphere and would not be expected to contaminate the hands or solid objects. Krypton has no place in the metabolism of the human body so its biological half-life would be short. Being a noble gas, it forms no chemical compounds that could retain the activity in solid form. There are no radioactive daughter products except a small percentage of Rb^{85}, half-life $\sim 10^{-5}$ sec, which is of no practical consequence. Of the many other isotopes of krypton that are originally present in the fission product mix, none have troublesome daughter products.

Although almost no published information is available on the radiological health aspects of Kr^{85}, considerable thought has been given to the subject by health physicists at Oak Ridge. In personal conversations these authorities indicated that external exposure due to contamination of the atmosphere with Kr^{85} would be the major consideration rather than inhalation or ingestion of the contaminated air. They estimate that sources commonly used in beta gaging, 5–50 mc, present no serious hazard in large, well-ventilated rooms, even in case of rupture.

The safety factor is further enhanced by the fact that source loss would most probably be by a slow leak, in which case the activity would be dissipated by air currents and produce no appreciable concentration. Moreover, a leak, even a relatively slow one, would quickly cause a loss of calibration of the beta-gaging instrument, thus providing a very sensitive automatic warning system.

For a source manufacturer, Kr^{85} is a very satisfactory material to handle. An exhaust hood over the working area provides personnel protection. There is no costly lost time or equipment contamination from spills that interrupt production with other forms of activity. Scrub, wash and wipe tests have no significance on Kr^{85} sources. Simpler, less costly and faster test procedures may be authorized. This would speed delivery to impatient customers.

No special mention has been made of the 0.65% of 0.54-Mev gamma radiation that is produced by Kr^{85} since it does not appear to be more troublesome, in the source strengths used, than the Bremsstrahlung produced by a typical Sr^{90} source.

The table summarizes the pertinent properties of three sources useful in beta gaging.

Pertinent Characteristics of Three Beta-Gage Sources

	Sr	*Kr*	*Tl*
Half-life* (*yrs*)	25	10	4
Principle beta energy* (*Mev*)	2.18	0.695	0.765
Decay rates† (apparent) (*mg/cm²/mo*)	0.43	0.23	0.6
Half thickness in Al foil‡ (*in.* × 10^{-3})	19	3.6	4.2
Absorption relative to Tl	0.22	1.2	1
Stray field	Large	Small	Small
γ-radiation	None	0.6%	None
Bremsstrahlung	Appreciable	Low	Low
Available specific activity* (*mc/gm*)	Carrier-free	450,000	>50
Price* (*$/mc*)	0.50	0.05–0.015	5.00–0.75
Self-absorption	Low	Low	High
Thickness range (*mg/cm²*)	20–500	0–80	0–90
Source preparation	Elaborate encapsulation procedures	Strength and shape easy to control	Electroplateable; strength adjustable
Loss in window	Low	50%/mil stainless	50%/mil stainless
Safety	High toxicity	No ingestion problem	Some ingestion hazard

* From Radioisotopes Catalog and Price List, ORNL (1956); prices depend on quantity purchased.

† Expected rate of drift in apparent weight per unit area due to source decay; see p. 66 for method of calculation.

‡ Approximate experimental values.

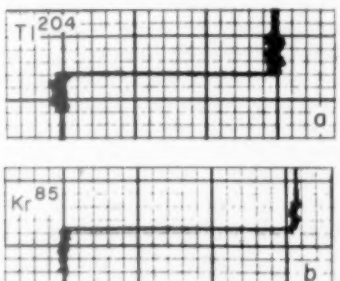

FIG. 3. Comparison of response of complete commercial weight recording instrument with Tl^{204} and Kr^{85} sources

BIBLIOGRAPHY

1. G. B. Foster, Industrial thickness gages, Nucleonics **14**, No. 5, 66 (1956)
2. W. J. Arnold, E. J. Wilson, C. Evans, J. Chadwick, J. Eakins. "The preparation and possible industrial uses of krypton-85 and tritium," Proceedings Radioisotope Conference, vol. 2, p. 59 (Butterworth's Scientific Publications, London, 1954)

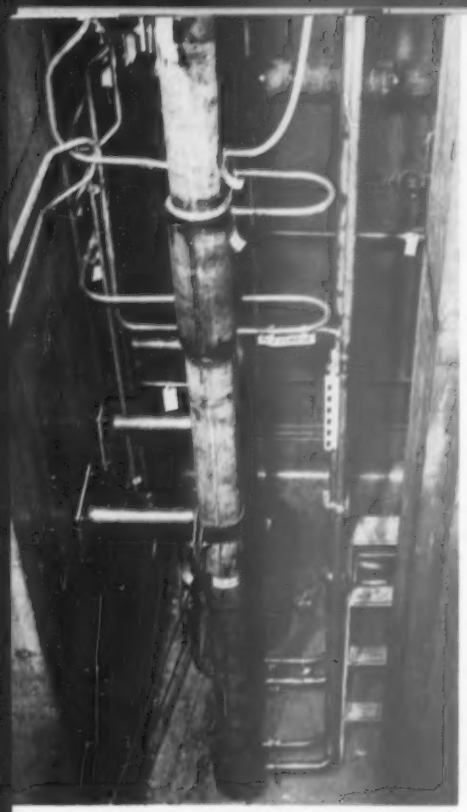

FIG. 1. Typical cubicle in Thorex pilot plant for segregating units in process line. This view shows bottom section of partitioning column. After column tests were completed, paper tags, ladder, etc., were removed and front of cubicle sealed with concrete blocks. Contaminated blocks are discarded when removed

Decontamination of Processing Plants

Good planning—built-in decontamination system, minimum of contamination traps, and effective procedures—saves time and personnel exposure in directly maintained plants. Thorex and Purex experiences show the practicality of this philosophy

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DIRECTLY MAINTAINED reactor-fuel-processing plants are those maintained by conventional means after the processing equipment is decontaminated to safe working levels. Fast, efficient decontamination can be achieved if the plant contains built-in decontaminating equipment and the operating personnel have effective reagents and procedures.

Processing equipment is usually decontaminated when emergency repair is necessary or a shutdown for preventive maintenance is scheduled. Multipurpose plants (capable of processing several fuel types) require equipment cleansing when feed materials are to be changed. This permits equipment modification to accommodate the new fuel and removes residual fission products that can contaminate the new process solutions.

The extent of decontamination—plant-wide or a few pieces of equipment—and the final radiation levels to be achieved depend on the time required by maintenance personnel to install or repair equipment or the requirements for changing to a different feed material. For example, if a mechanical failure occurs that may take 1 or 2 hr to repair, only the equipment in the immediate vicinity of the failure would be decontaminated sufficiently to allow the required working time. If extensive equipment alterations are to be made, the entire plant would be decontaminated to allow 8-hr working time in the processing cells.

Design for Decontamination

A directly maintained plant requires equipment segregation, decontamination procedures and equipment, and strict control of radiation exposure of maintenance personnel (*1*).

Process equipment containing radioactive solutions is segregated either as single units or as a group of closely related units according to function and activity level. In the Thorex pilot plant at ORNL, the cells, which are concrete-walled rooms in series along the length of the process building, are further subdivided into cubicles by concrete- or lead-block walls. Equipment is placed inside the cubicles and is enclosed with a removable front face of loosely stacked blocks (Fig. 1). Each cubicle is accessible from a low-radiation area. Equipment is arranged so that the activity level in the process cells decreases from one end of the plant to the other. Only equipment requiring emergency repair is decontaminated; shielding protects the craftsmen from contaminated equipment.

Each tank in the plant is equipped with one or two internal jets (Fig. 2) for spraying decontamination solution. The solutions are prepared in makeup tanks above the cells (Fig. 3) and distributed to the process tanks through a panel above the cells and below the makeup tanks (Fig. 4). The cubicle and cell walls can also be sprayed with decontaminating reagents through solid-cone spray nozzles.

All process equipment is constructed of stainless steel, and the walls and floors of the cubicles and cells are covered with thin-gage stainless steel. A drain line from each cubicle to a central cell sump carries off reagents.

Vessels are designed so that solutions can be removed easily. There are few cracks, crevices, flanges, and other traps in which radioactive particles might be held.

Decontamination Procedures

An important phase of decontamination is to shut the plant down properly. This is to recover all valuable material held up in the process equipment and to prevent the displacement of fission

products to downstream equipment, which would overly contaminate the equipment. During shutdown, process reagents that might precipitate decontamination reagents are removed (an alternative is to use a decontamination reagent that is compatible with the process reagents).

Decontamination temperature of 60°–85° C for 0.5–1.5 hr with agitation has been sufficient in most cases. The flow patterns for the reagents should be planned to obtain the maximum reuse of reagents and permit simple solution-transfer procedures. Reagent flow from one vessel to another should be in the direction of higher radiation level.

Since decontamination is evaluated by radiation survey of the equipment before and after treatments, the survey should be planned carefully to obtain reliable and consistent data. If possible, a preliminary survey should be made and specific locations for future measurements should be determined. The measurements should be taken each time at these same locations. The surveyors should be trained to be conscientious and accurate, and the instruments should be accurately calibrated. This is particularly important for emergency jobs.

The bulk of the activity is removed fairly easily, provided the activity is not trapped in blanked lines or crevices. For example, the feed-adjustment tank in the Thorex plant is installed inside a large open-top container that is not equipped with decontamination equipment. Decontamination of this tank is difficult because activity is retained in the container. The tank itself can be decontaminated in five treatments of 30% HNO_3 alternated with five treatments of 20%-NaOH–2%-Na-tartrate, but the external container requires much more decontamination to remove its activity. In another plant, an evaporator for the aqueous waste stream from the extraction column was almost impossible to decontaminate in place because activity was retained in blanked-off lines from the evaporator.

Plant-Wide Decontamination

Most plant-wide decontamination follows a standard pattern. After radioactive feed to the extraction system is turned off, nonradioactive feed solution (U in a Purex plant and Th in a Thorex plant) is pumped to deplete the system of valuable materials, after which the aqueous and organic streams

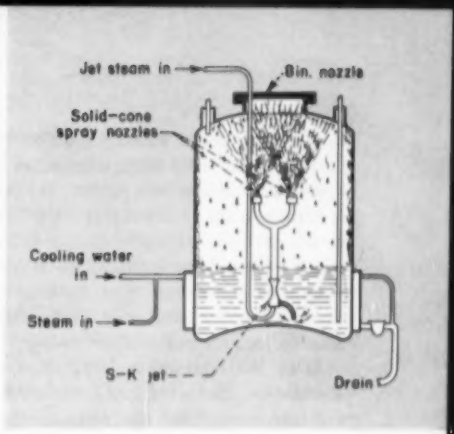


FIG. 2. Jet circulation system for decontamination mounted inside process tank. Jets are mounted on steam-supply line that is welded to flange plate over 8-in. inspection nozzle. Decontaminating solution is picked up by jet suction line from bottom of tank and is discharged through spray nozzles. Solution is sprayed to top of vessel with sufficient force to flow across entire top and trickle down walls

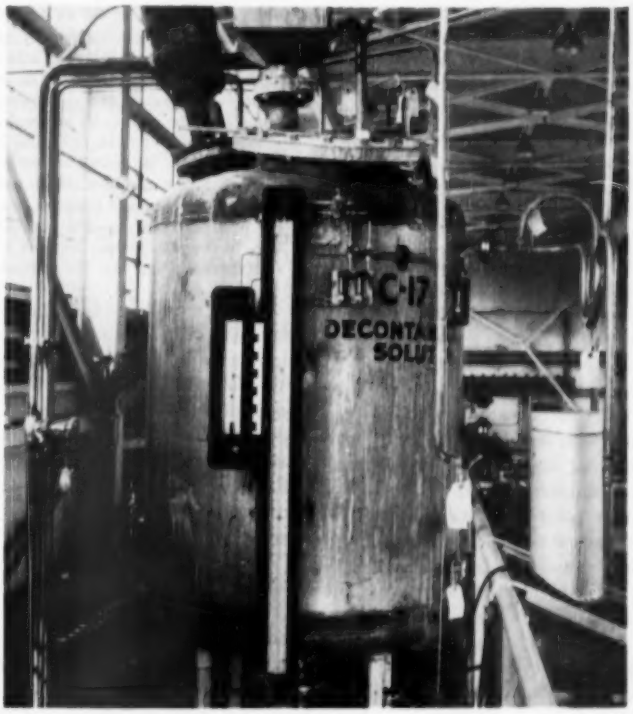
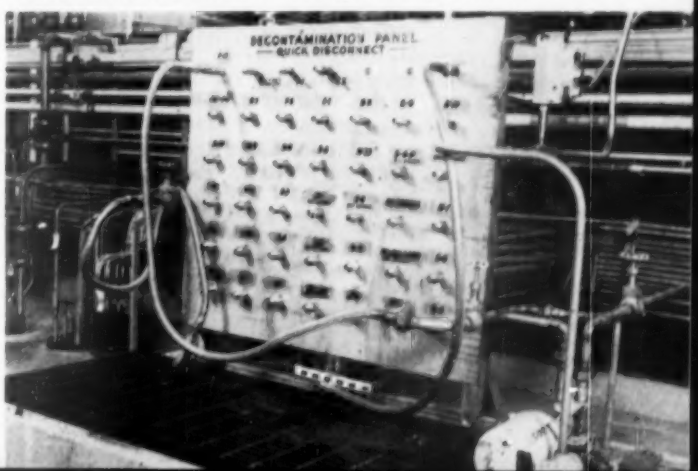


FIG. 3. Decontamination-solution makeup tank is on roof over cells. Solutions are dropped by gravity through decontamination panel to cells. Each makeup tank is equipped with solution-addition funnel, agitator, heating coil, and purge-type liquid-level and specific-gravity instrumentation

FIG. 4. All decontamination lines from cells terminate at this panel. Steam, water, and solutions are routed to cell vessels and cubicle sprays by plugging feed lines to proper nozzles. Quick-disconnect couplers are used; both halves of coupler have spring-loaded check valves that seat when coupler is disconnected



may be continued without feed to deplete the system of natural uranium or thorium. During this period, column operation must be carefully controlled to prevent the displacement of interfacial solids from columns to downstream equipment. The system is then flushed with water or dilute nitric acid to remove particulate matter.

After the equipment is emptied of all solution, decontamination solutions are introduced and the equipment is contacted according to plan. After five to ten passes of reagents have contacted the equipment, the equipment may be decontaminated sufficiently for surveyors to measure the radiation levels of the equipment and to pinpoint localized contamination. In this manner, decontamination treatments can be applied where most needed. After the equipment is sprayed or hosed down, operators enter the process cells to scrub the localized contamination on external surfaces of equipment, walls, and floors. If further internal treatments are ineffective in decreasing localized internal contamination, 3-20 reagent (3%-HF–20%-HNO_3) may be used or the contamination may be shielded with lead.

Following are the results of plant-wide decontaminations.

Thorex pilot plant (*2*). After approximately 3 tons of highly irradiated thorium metal had been processed in the Thorex plant, the plant was shut down, cleansed of uranium and thorium, and decontaminated (see Figs. 5 and 6). Twenty-four major pieces of equipment in three process cells were decontaminated in 19 days.

Before decontamination was begun, the equipment was subdivided into eight groups, and flow patterns were established for each group. The groups were: dissolution and feed adjustment, feed pumping, extraction column and associated head pots and tanks, partitioning column, stripping column, rework system, solvent recovery, and recovered solvent storage (Fig. 7).

Solutions were added to the least radioactive vessel in a group and transferred to succeeding tanks of higher radioactivity. Side transfers of reagent were made to contact overflow lines, auxiliary jets, and piping. The solutions were allowed to recirculate in each tank at 60°–85° C for 1 hr minimum. Vessels without recirculation jets were heated by steam jackets, and the solutions were agitated or sparged. Columns were pulsed.

The feed-preparation and feed-pumping equipment was decontaminated from 100 r/hr (estimated) to 75 mr/hr background (radiation measurements taken at about the middle of the cubicles, 1–3 ft away from the equipment). The extraction column, rework system, and miscellaneous-waste-collection tank were decontaminated from 100 r/hr (estimated) to 75-mr/hr background, and the partitioning and stripping columns, the thorium and uranium product-handling equipment, and the solvent-recovery system were reduced to 10-mr/hr from 2–10 r/hr.

Except for the dissolver, which required twenty treatments, the feed-preparation and feed-pumping equipment required five treatments of 30%-HNO_3 alternated with five treatments of 20%-NaOH–1%-Na-oxalate. For each treatment, 900 liters of solution were used. The extraction column, rework system, and miscellaneous-waste-collection tank were decontaminated with four 30%-HNO_3 treatments alternated with four 20%-NaOH–2%-Na-tartrate treatments (700 liters per treatment). The remaining equipment was decontaminated with two 30%-HNO_3 treatments and two 20%-NaOH–1%-Na-oxalate (or 2%-Na-citrate) treatments.

The effluent reagents from the equipment were analyzed. Pa removal appeared to limit decontamination of the feed system, both Pa and Nb removal appeared to limit decontamination of the partitioning and rework systems, and Nb to limit decontamination of the stripping and solvent systems.

A total of 160 reagent treatments were used, requiring 480 hr for solution addition, heating, cooling, and transfer. Only half the normal operating force was utilized. If the full crew had been utilized, it is estimated that the 19 days for decontamination would have been halved and the average contact time reduced from 3 to 1.5 hr.

The cost per treatment was $222, of which $81 was for labor, $14 for materials, $66 for analytical services, and

Effectiveness of Decontamination

	Radiation level (r/hr)	
Cell	*Before decontamination**	*After decontamination*
Feed preparation	~500–1,000	0.050
Extraction column	~100	0.035
Cell II†	1	0.035
Solvent recovery	0.35	0.030
Acid recovery	5	0.020

* Readings taken in Purex plant 4 ft above floor and 6 ft inside cell doorway.

† Contained first-cycle partitioning and stripping columns and associated equipment, and second U and Pu cycles.

These Reagents . . .

Over a period of several years, experience in various ORNL pilot plants has led to the following generalities: Nitric acid (30%), oxalic acid (10%), and mixtures of caustic and oxalic acid or tartaric acid are the most all-around useful decontaminating reagents. The most efficient reagent of all is 3-20 (3%-HF–20%-HNO_3), but it is used as a "last-resort" reagent because of its corrosiveness (3). Citric acid, periodic acid, ammonium bifluoride, and versene are typical reagents that were tried and found to be less effective decontaminants.

. . . Which Satisfy These Requirements . . .

Mildly corrosive to process equipment
Stable to heating and aging for several hours
Inexpensive
Neutralize one another
Allow convenient waste disposal (2)

. . . Were Used for Decontaminating Stainless Steel

Radioactive contamination on stainless steel either is absorbed on the surface or does not penetrate very deeply, and a large part of it may be easily removed. Decontamination methods usually involve one or more of the following: detergent cleaning, forming a soluble complex of the contaminant, solution of the contaminant in strong acid, and removal of the surface by physical or chemical means (3).

When caustic-tartrate solutions are alternated with nitric acid (e.g., 20%-NoOH–2%-Na-tartrate is alternated with 30% HNO_3 in the Thorex pilot plant), the alkaline solution forms a complex with contaminants such as zirconium and ruthenium. However, the steel surface becomes passivated after about 4 hr. The acid treatment removes the passivity (also dissolves activity) and prepares the surface for further decontamination by caustic-tartrate solution (4). Of course, more corrosive reagents remove the steel surface along with the contamination.

$61 for overhead. Thus the total cost was $35,520.

Purex pilot plant. After about 150 days of operation, processing irradiated uranium metal, 40 pieces of equipment in four cells were decontaminated.

This program was conducted similarly to the Thorex-plant decontamination. The 3-20 reagent was judged to be the best decontaminant for stainless steel (types 347 and 309 SNb) and was valuable in removing the last 5–10% of the activity on contaminated equipment when other chemicals were ineffective. The corrosion of sound stainless steel was apparently not significant; however, faulty welds that had resisted concentrated nitric acid failed quickly when treated with HF solutions. No tanks were affected, but several small-diameter pipes had to be rewelded due to attack at the welds.

Internal sprays were effective in reducing the volume of decontaminating reagent required. Tanks with sprays were cleaned with the use of approximately one-half the total volume of wash required for comparable-sized tanks not equipped with a spray.

All large equipment was decontaminated in place except for a reboiler that was unbolted from the system to remove corrosion specimens. Several small pieces of equipment, such as jets, centrifugal pumps, valves, and short sections of piping, were removed from the cells when further treatments were ineffective. These items were decontaminated piecemeal or discarded if the estimated cost of decontamination was greater than replacement.

This program was much more developmental than the Thorex decontamination program, being conducted at a slower pace. Also the Purex plant had more equipment at higher radiation levels than the Thorex plant. Except for feed-preparation equipment, the equipment did not have internal sprays. Consequently, 75 days were required to decontaminate the plant. Approximately 6,000 man-hr of operator labor was expended, and maintenance services, for cutting and removing lines, removing and replacing jets and valves, loosening flanges and welding, cost $2,500 for labor and materials. The cost for chemicals was $5,400. The initial and final radiation levels are given in the table.

Emergency Decontamination

The operating crews in both the Thorex and Purex plants have become experienced in decontaminating a portion of the plant for emergency maintenance or equipment modifications. The following two examples are typical of emergency decontaminations.

Feed-preparation equipment. To alter a vapor line from the feed-adjustment tank (S-2, see Fig. 5) to the acid fractionator (S-9), the equipment in two cubicles in the Thorex plant was decontaminated in 8 days. Had it not been for the activity held up in the container around S-2 tank, decontamination could easily have been completed in half the time.

The internal surfaces of S-2 tank (450 gal) were decontaminated in seven treatments (700 liters each) with 30%-HNO_3 and five treatments with 20%-NaOH–2%-Na-tartrate. (Five treatments of each would have been sufficient. Activity from the container obscured the radiation surveys.) The container was treated with five 30%-HNO_3 and four 20%-NaOH–2%-Na-tartrate treatments. The final radiation level in the cubicle was 300 mr/hr.

The feed tank, acid fractionator, extraction column, and aqueous-waste surge tank were decontaminated in 35 min working time. The feed tank required three acid and two caustic-tartrate treatments (100 liters per treatment in a 900-liter tank). The acid fractionator (16 ft tall by 18 in. dia)

Thorex, Purex—What Are They?

● THE THOREX PILOT PLANT (5) was constructed in 1954 to develop and demonstrate chemical and engineering flow sheets (see accompanying flow sheets) for the Thorex process. This process was designed to separate and decontaminate U^{233} and thorium from fission products. Feed solution is prepared (Fig. 5) by dissolving irradiated aluminum-clad thorium metal slugs in nitric acid. Acid vapors pass to fractionator; recovered acid is reused, lean acid is discarded. Adjusted feed is transferred to head tank and to extraction column (Fig. 6).

The process equipment is contained in three process cells, which are further subdivided into cubicles by concrete- or lead-block walls. Each cubicle contains one piece or a few pieces of closely related equipment so that for emergency repair, only one or two cubicles need be decontaminated.

Nonradioactive solutions are prepared in a makeup area, which is shielded from the cells by a 5-ft-thick wall. Process solutions are sampled by means of a shielded sampling system (6), which is located in a gallery along the outside of the cell wall. Instrumentation for the process is located on a central control panel in the control room.

● THE PUREX PILOT PLANT was operated from 1950 to 1953 to develop Purex process (ref. 1 gives flow sheets), for separating the U, Pu, and fission products of irradiated fuel by solvent extraction. This plant was constructed in the first four cells of the radiochemical separations pilot-plant building in which the Thorex pilot plant is presently housed. The layout of the plant was similar to all directly maintained plant layouts. This plant contained a lot more equipment than Thorex does, for it had a second uranium cycle and a second plutonium cycle. The equipment was installed in the 20-ft-square cells without being shielded in cubicles.

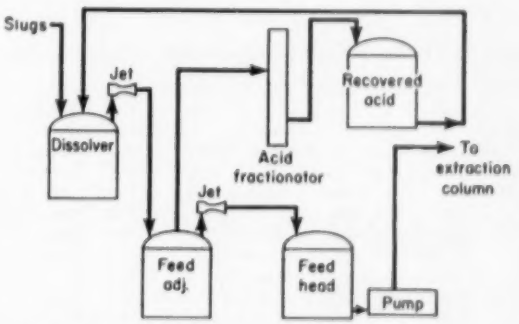


FIG. 5. Thorex feed-preparation flow sheet

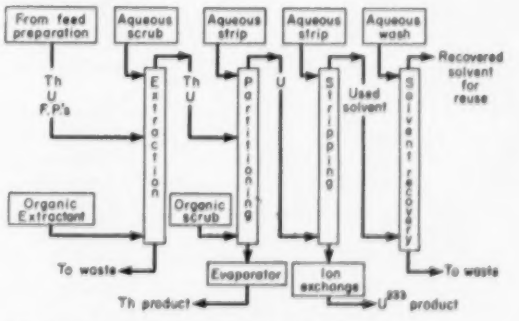


FIG. 6. Thorex solvent-extraction flow sheet

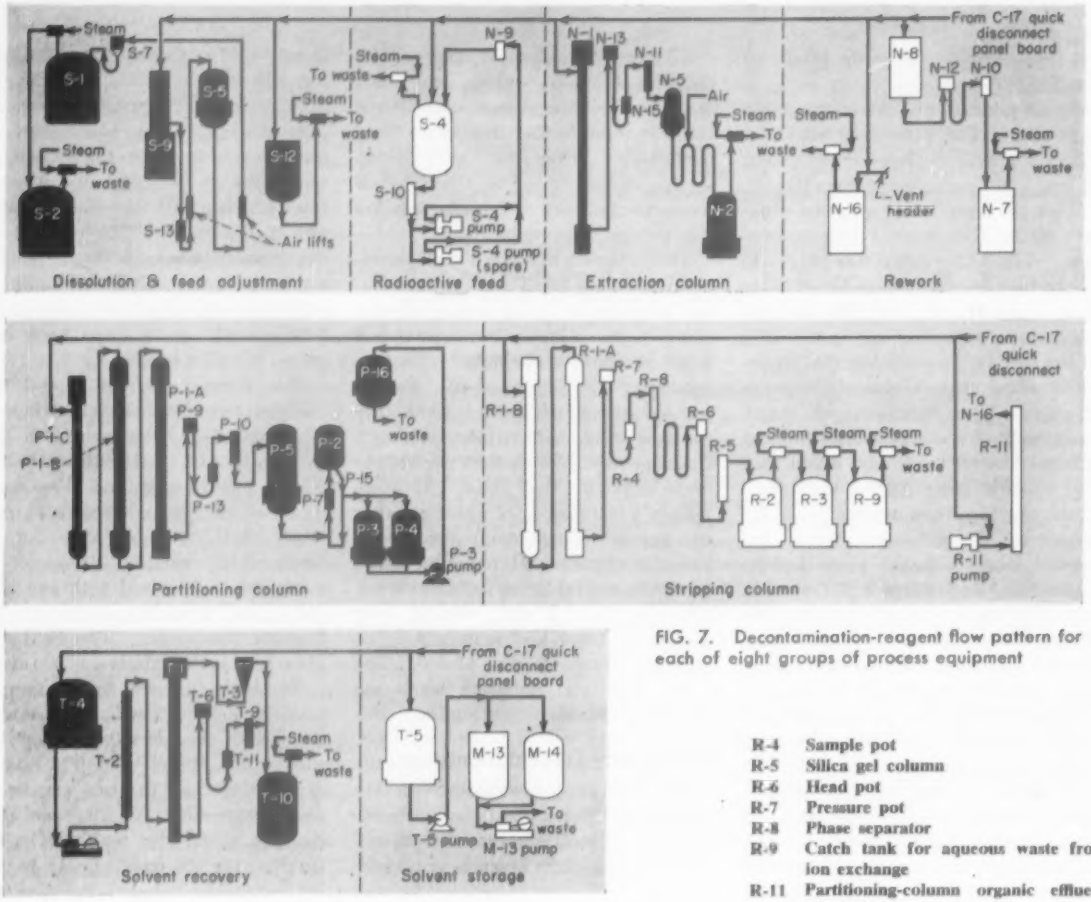


FIG. 7. Decontamination-reagent flow pattern for each of eight groups of process equipment

Key to Thorex Plant Components Shown in Fig. 7 (above)

C-17 Decontamination-solution make-up tank
M-13 TBP-extractant head tank
M-14 Organic scrub solution head tank
N-1 U, Th extraction column
N-2,5 Extraction-column aqueous-waste-solution catch tank
N-7,8 Aqueous rework tanks—waste containing excess U^{235} prepared for recycle to solvent extraction
N-9 Extraction-column feed solution head pot
N-10,11 Phase separators
N-12,13 Pressure pots
N-15 Sample pot
N-16 Miscellaneous-waste catch tank
P-1-A,B,C U, Th partition column
P-2 Vapor scrubber
P-3,4 Conc. Th catch tanks
P-5 Stream stripper and surge tank
P-7 Partition-column Th solution evaporator heater
P-9 Pressure pot
P-10 Phase separator
P-13 Sample pot
P-15 Evaporator loop
P-16 Conc. Th decay storage tank
R-1-A,B U stripping column
R-2 Catch tank for U solution from stripping column
R-3 Head tank for U solution from R-2 to ion exchange
R-4 Sample pot
R-5 Silica gel column
R-6 Head pot
R-7 Pressure pot
R-8 Phase separator
R-9 Catch tank for aqueous waste from ion exchange
R-11 Partitioning-column organic effluent stand pipe
S-1 Dissolver tank
S-2 Feed-adjustment tank
S-4 Feed solution head tank
S-5 Recycle acid catch tank
S-7 Vapor separator
S-9 Acid fractionator
S-10 Feed solution flow-rate checker
S-12 Acid catch tank
S-13 Acid cooler
T-1 Waste-solvent recovery column
T-2 Preheater
T-3 Centrifuge
T-4 Stripping-column organic waste catch tank
T-5 Recovered-solvent catch tank
T-6 Pressure pot
T-9 Flow checker
T-10 Aqueous waste from T-1 catch tank
T-11 Sample pot

required two acid and two caustic-tartrate treatments of 400 liters each, and the extraction column and waste surge tank required four acid treatments (300 liters each) and two caustic-tartrate treatments (300 liters each).

Partitioning column. A weld had failed at the bottom of the Thorex partitioning column. The column was internally decontaminated in 24 hr with two treatments of 30% HNO_3 alternated with two treatments of caustic tartrate. External decontamination was accomplished in 2 hr by water washing, scrubbing with sulfamic acid, and a final water rinse. The radiation level of the column was reduced from 8,000 mr/hr to 80 mr/hr. Final background in the cubicle was 30 mr/hr.

BIBLIOGRAPHY

1. H. K. Jackson, G. S. Sadowski, NUCLEONICS **13**, No. 8, 22 (1955)
2. K. H. McCorkle, W. R. Winsbro. Decontamination of the ORNL Thorex pilot plant, ORNL-2058 (1956)
3. D. O. Campbell. Removal of fission products from stainless steel, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 9, p. 551 (United Nations, New York, 1956)
4. R. D. Baybarz, ORNL, personal communication
5. A. T. Gresky. Solvent extraction separation of U^{233} and thorium from fission products by means of tributyl phosphate, in "Intl. Conf. on Peaceful Uses . . . ," vol. 9, p. 505 (United Nations, New York, 1956)
6. H. G. Duggan, J. W. Landry, NUCLEONICS **12**, No. 11, 67 (1954)

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Delay-Line Chamber Has Large Area, Low Capacitance

By WILMOT N. HESS, H. WADE PATTERSON, and ROGER WALLACE
Radiation Laboratory
University of California
Berkeley, California

We have found a solution to the principal problem that makes it difficult to design ion chambers with large plate areas—large electrical capacitance.

The solution is to connect a series of plates to make a delay line. In this way the chamber presents its total plate area to the flux it is counting, but each pulse produces a high voltage by charging only a single pair of plates. The method is applicable to the construction of any pulse ion chamber in which it is desirable to have a plate area of the order of 50 ft².

Our bismuth-fission chamber, shown in Fig. 1, is designed for very-high-energy neutrons. It has a sensitivity of 1 count for every 300 neutrons/cm².

Chamber Design

The chamber is intended for health-physics surveys of neutron and proton fields as well as for applications in cosmic-ray and high-energy nuclear-physics research. To eliminate response to gamma rays and nuclear-star events, the plates are coated with a material that has a high fission threshold, and the device is operated so that only fission events are detected. Above 1 Mev, bismuth is the only element suitable for this purpose (*1*). Its fission threshold is near 50 Mev for neutrons or protons, and at 270 Mev the cross section is 180 millibarns. We do not have measurements at greater energies than this, but there is reason to believe that the cross section does not rise much higher.

The fission fragments from bismuth have a range of ~1 mg/cm², and there is some evidence that only the top ½ mg/cm² of a bismuth coating is "effective" in producing detectable fission events. As a result it was decided to space the plates ¼ in. apart, providing approximately 1 mg of gas path length when the pressure is 1 atm and the fragment's path is perpendicular to the plates. Due to the limited effective depth of the bismuth, it is necessary to provide a large area to have a significant counting rate.

Bismuth fission chambers have been made before (*2*), but not with nearly the area of this one. The total plate area in our present chamber is 63,000 cm², so that we have 31.5 gm of effective Bi, even though the coating is actually 1 mg/cm² deep.

FIG. 1. Bismuth fission chamber. Vacuum case is made of 0.5-in. dural. Low-noise preamplifiers and signal-control box are shown on top of chamber

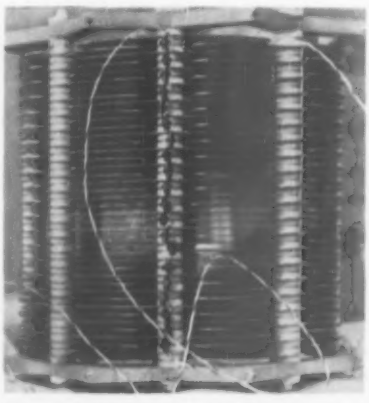


FIG. 2. Interior of chamber showing spacing of plates and inductances that connect alternate plates

Inside the chamber 43 plates 12 in. in diameter and 0.040 in. thick are spaced 0.25 in. apart on eight rods (Fig. 2). Alternate plates are supported (as one unit) by four of the rods, but are separated by the 0.25-in. spacings from the other plates and their four supporting rods. The rods are fastened at each end to heavy rings, in turn held in place in the case by eight radial setscrews. This rugged construction was chosen to reduce microphonic response. The plates are coated on each side by vacuum evaporation of 1 mg/cm² of Bi.

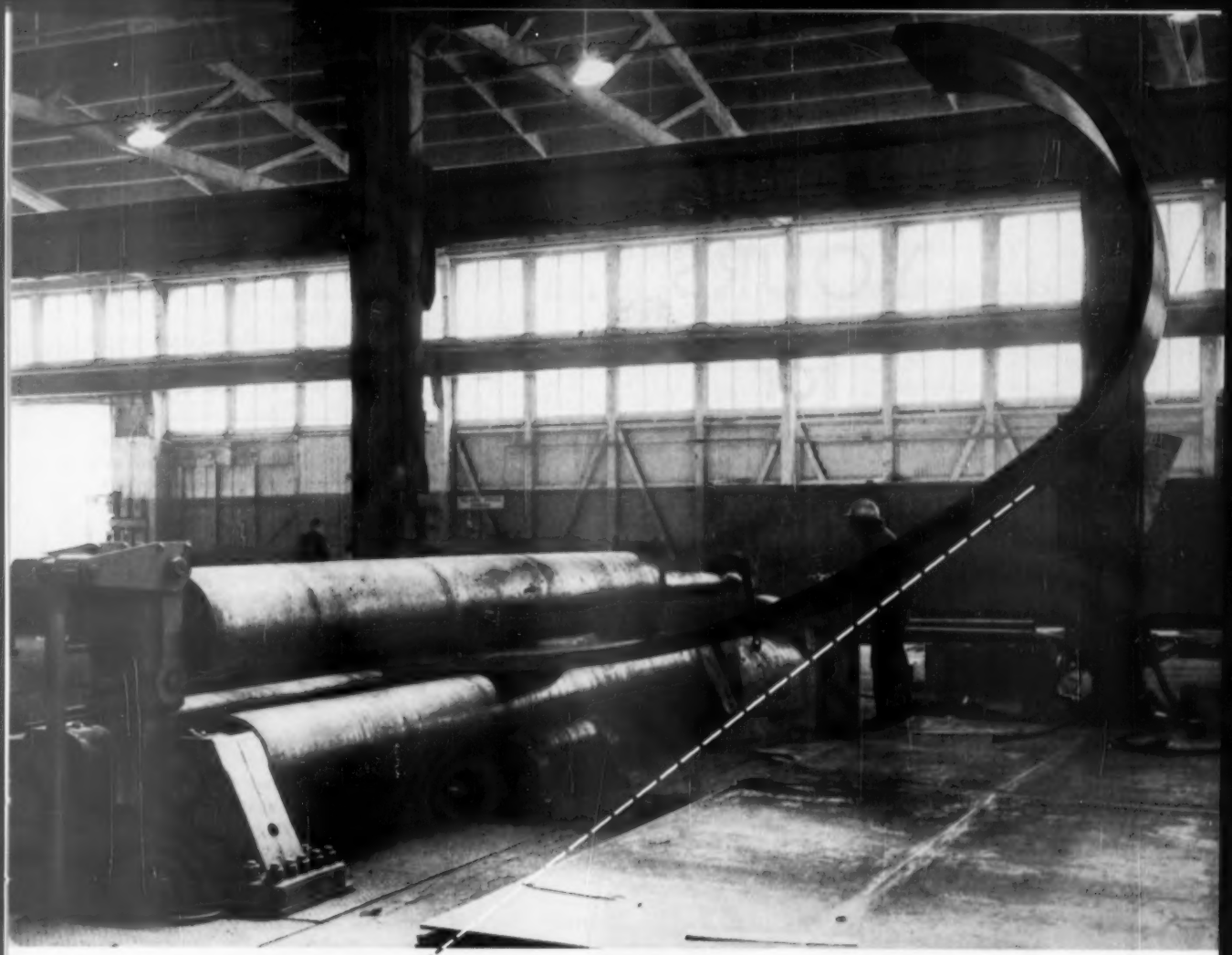
Electrical Problem

It was at first intended to connect the plates in series, with 5 kv across the whole stack to provide a field strength of about 200 volts/cm. The series connection did not provide uniform or adequate sensitivity across the stack; fissions occurring on more remote plates could be detected only with reduced sensitivity. In addition, the high voltage necessary for the series connection gave rise to high-voltage breakdowns.

A simple connection of alternate plates in parallel, while it permitted use of a low voltage, gave an electrical capacity of about 8,000 $\mu\mu$f, which made the signals much too small to detect. To isolate each plate and yet take advantage of the large total area of the 43 plates, alternate plates were connected to individual triodes, and the plates of the triodes were tied together. This system did not work because the noise of all the triodes was competing with a desired signal from only one.

Solution

What was needed was a method of allowing one of each pair of plates to be connected to the input of the preamplifier when a signal was available between that particular pair of plates, but disconnecting the capacity of that pair of plates when a signal was not present. This arrangement (as suggested by William Goldsworthy and James Robison of this laboratory) is achieved as shown in Fig. 3. One set of alternate plates is connected directly to the negative side of a 300-volt battery through a simple filter. The plates of the other set are connected to one another by 200-μh inductances forming, in conjunction with the interplate capaci-



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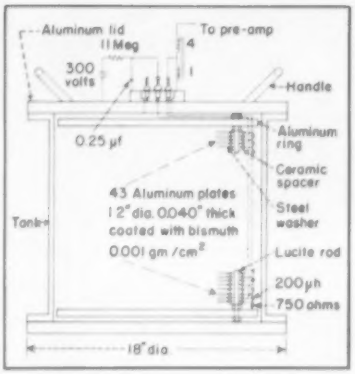

FIG. 3. Interior arrangement of bismuth fission chamber. Plates are spaced by ceramic insulators and washers along bars that are held to case by supporting rings at each end. Half the plates are connected to battery contained in the signal-control box on top of chamber. Rest are connected in series through 200-μh inductances, making them into distributed delay line having over-all delay of about 5 μsec. One end of line is terminated in characteristic impedance of 750 ohms; other end is connected to autotransformer that serves to match impedances

tances, a delay line. To eliminate reflections one end of this line is terminated in its characteristic impedance by a 750-ohm resistor. The other end of the line is connected to a pulse autotransformer, giving a 5-to-1 voltage gain. This provides better impedance matching to the input of the preamplifier.

There is a 5-μsec delay along the entire line. Therefore a particular signal may be delayed 0–5 μsec. For coincidence work to better than 5 μsec, both ends of the delay line can be brought out. If the resulting double pulses were detected, the location of the pulse in the chamber along with its resulting delay could be determined to perhaps 0.25 μsec.

The signal from the pulse transformer is amplified by 100 db in a low-noise preamplifier and low-noise linear amplifier of UCRL design. The average signal coming from the pulse transformer is about 100 μv. Since the counting rates with this chamber are often low in spite of the large amount of effective bismuth, the pulses coming from the linear amplifier are both photographed and recorded in duplicate on registers for a check on the long-time stability of the electronic circuits. A conventional driven-sweep oscilloscope and moving-film camera are used. Calibration pulses of a known size are automatically fed into the circuit between the pulse transformer and pre-

amplifier at regular intervals and recorded on the film as a check of reliability. Discriminators controlling the registers are gated off when calibration pulses are being fed in.

The chamber is filled to 20 lb/in^2 absolute with 95% argon and 5% CO_2. This is an optimum pressure—more pressure increases recombination, and less allows the average fission fragment to hit the opposite plate before reaching the end of its range. It has been found, by reversing the polarity, that the bismuth on both the delay-line-collector set of plates and the high-voltage set is effective. That on the high-voltage set is ~2–3 times as effective as that on the delay-line set.

Response

As the 184-in. synchrocyclotron is not in operation at present, the chamber has been partially calibrated during a run at the UCRL Bevatron. Here

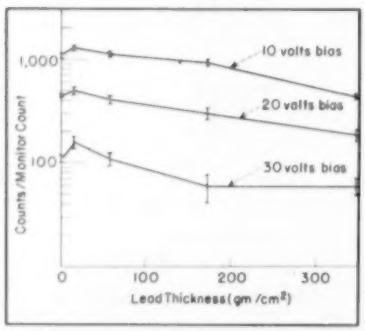

FIG. 4. Transition curve for lead up to 12 in. thick for neutral beam of the University of California Bevatron. Values plotted are due to bismuth only; neutral-chamber effect has been subtracted. Curves indicate no measurable response to γ-rays, though they constitute major part of beam. Slopes of curves are consistent with neutron attenuation in lead.

6.2-Bev protons struck a target producing a variety of particles. The magnetic field of the Bevatron deflected all the charged particles away from the chamber, leaving principally neutrons and gammas of several Bev. A transition curve, shown in Fig. 4, was run using 0, 0.5, 2, 6, and 12 in. of lead. A twin chamber having no bismuth was used to subtract any effect that might be caused by the aluminum plates. Above a few volts bias this subtraction proved to be small. The small slope of these curves is consistent with the attenuation of neutrons by lead and is equivalent to a mean free path of about

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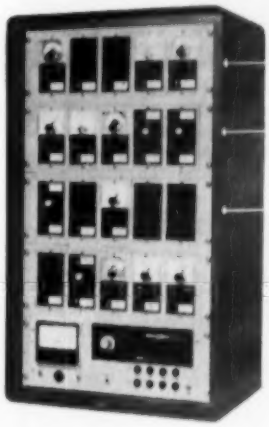

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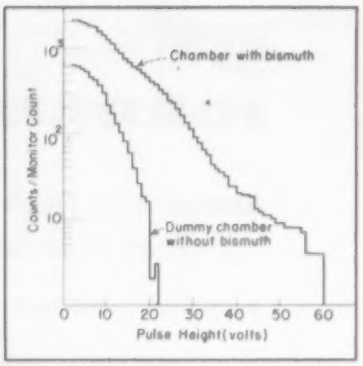

FIG. 5. Integral bias curves for bismuth-coated chamber and its twin with no bismuth. Above 20 volts bias, ratio of counting rates is as much as 500 to 1

200 gm/cm², which is as close to the geometric cross-section mean free path for lead of 180 gm/cm² as can be expected of these rough preliminary measurements. Apparently the response to gamma rays, known from other experiments to constitute about ⅓ the neutral-particle beam, is quite small, since no steep attenuation—which would be characteristic of gamma rays—is seen at all.

The relative integral bias curves for the chamber with the bismuth and for the twin control chamber without the bismuth are shown in Fig. 5. It is seen that under the worst conditions at 10 volts the ratio is 4 to 1, but that this has risen to 25 to 1 at 20 volts and above this is as much as 500 to 1. The difference in slopes of the bismuth and nonbismuth curves is interpreted as an indication that the processes responsible for the pulses are fundamentally different, namely, heavy-element fission on the one hand and light-element star formation on the other.

During the Bevatron run a comparison was made with a previously calibrated small chamber containing 1 gm of effective bismuth and having a sensitivity of 1 count per 10^4 n/cm² at 290 Mev. It was found that the large chamber had a counting rate, when extrapolated to zero bias, 37 times that of the little chamber, which is to be compared with a ratio of about 21 in the amount of effective bismuth contained. This measured ratio gives a sensitivity of about 1 count per 300 very-high-energy n/cm² (assuming that the fission cross section does not vary rapidly with energy above 300 Mev).

A Cf^{252} spontaneous-fission source (*3*) has been incorporated into each cham-

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ber, but for simplicity has not been shown in Fig. 3. The high voltage to this source can be switched off or on from the outside, making a fairly high counting rate of bona fide fission pulses available at any time for circuit test and calibration purposes. The integral bias curve arising from 500 Cf^{252} pulses is shown in Fig. 6. That the slope of this curve is much steeper than that arising from the bismuth fissions is interpreted as a result of the difference in the mechanics of the two fission processes themselves, and of the fact that the Cf^{252} is extremely thin.

This chamber will sometimes be used in the presence of charged particles, such as very-high-energy protons and

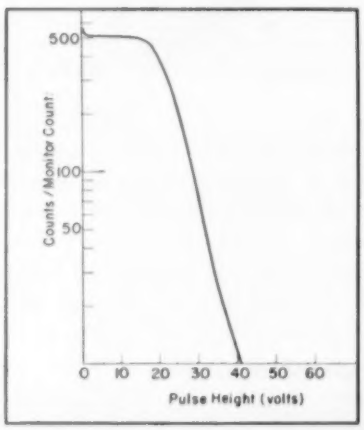

FIG. 6. Integral bias curve of 500 Cf^{252} spontaneous-fission pulses. Steeper slope of curve is thought to arise from energy difference between spontaneous californium fission and induced high-energy-neutron fission of bismuth

pions, which can initiate fissions as easily as neutrons can because their energy is so far above the Coulomb barrier potential. To separate the effect of the charged particles, a complete blanket of G-M tubes is being constructed for the bismuth-containing chamber, and each fission event will be recorded as being either in coincidence with a G-M pulse or not.

* * *

The authors wish to thank the operating crews of the UCRL 184-in. cyclotron and Bevatron for their cooperation in the experimental calibrations of this fission chamber.

This work was performed for the U. S. Atomic Energy Commission under contract W-7405-eng-48.

BIBLIOGRAPHY

1. E. L. Kelly, Clyde Wiegand, *Phys. Rev.* **73**, 1135 (1948)
2. Clyde Wiegand, *Rev. Sci. Instr.* **19**, 790 (1949)
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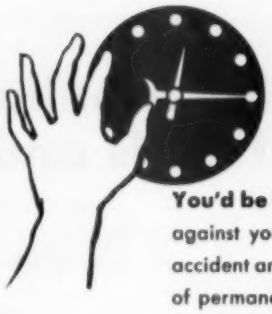

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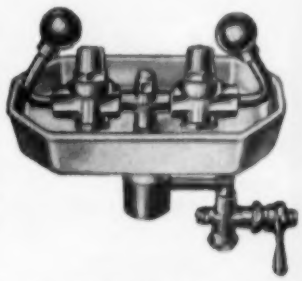

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Alpha-Scintillation Monitor for Hands and Clothing

By J. NICHOLLS*
Burndept Ltd., Erith, Kent, England

Protection of the employees in fuel-processing plants requires equipment that can detect alpha contamination on their hands or clothing at levels as low as 2.5×10^{-4} μc. Exposure to or ingestion of larger quantities of the pure alpha emitters would exceed the permitted level (*1, 2*).

A standard detector for checking operators' hands is the air-proportional counter (Fig. 1). For detecting Pu or Po, most installations use four such alpha detectors to scan both sides of both hands simultaneously.

Two major practical problems arise in the use of such counters:

First, the very fine anode wires tend to vibrate when the counter units are driven toward the hands. Such vibration produces spurious counts. This problem is aggravated by the fact that high-gain pulse amplifiers are necessary to amplify the small output pulses (0.1–5 mv) from the proportional counters. (By way of contrast a well designed alpha scintillation counter yields 10–500 mv under the same conditions.)

Secondly, because of the high voltages employed, dusty, humid atmospheres cause breakdown currents to flow—again leading to spurious operation.† In some instances air conditioning was installed to offset this effect, but this increased costs.

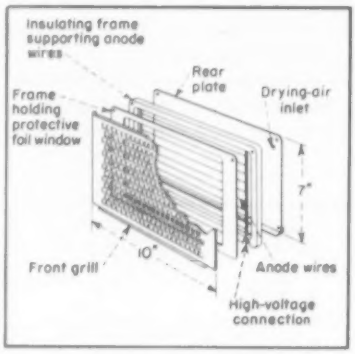

FIG. 1. Typical large-area air proportional counter for alpha counting

Scintillation Counter

To circumvent the foregoing difficulties we used an alpha-scintillation counter.

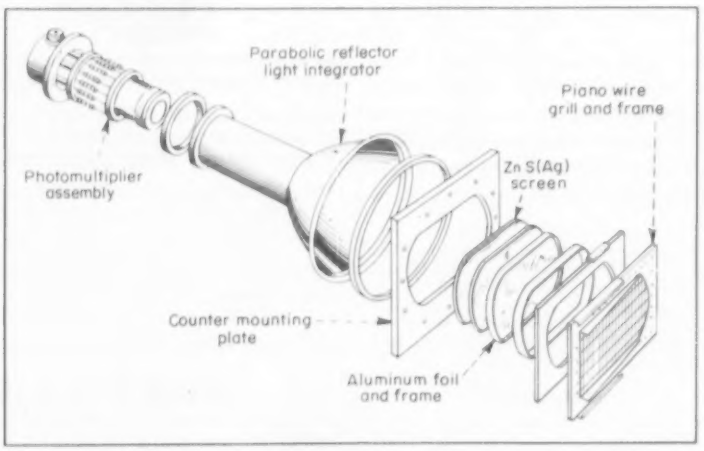

FIG. 2. Exploded view, alpha hand counter unit

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† An air-proportional counter that is insensitive to humid conditions and microphonics is currently under test (*3*).

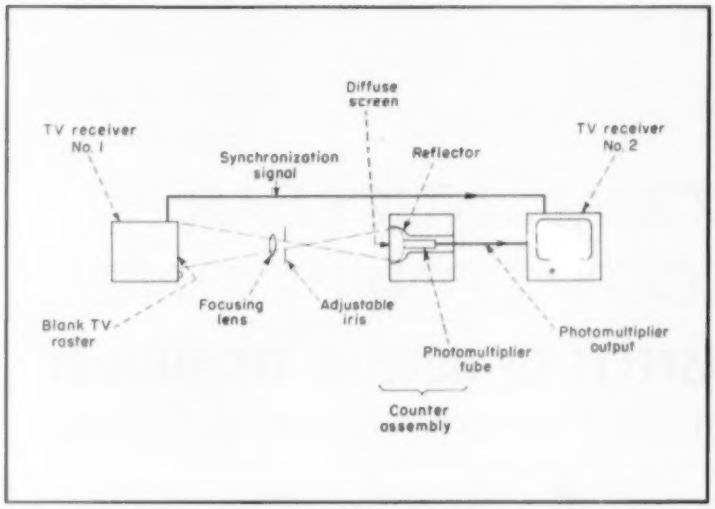


FIG. 3. Flying-spot scanning system for reflector evaluation. Parabolic reflector gave best results when compared with truncated-cone and pyramid shapes—>90% of center response at maximum usable radius

For high output and good reliability the alpha-scintillation counter includes a light-tight alpha window, a silver-activated zinc-sulfide phosphor, and a photomultiplier. One problem in the design of the equipment was that of using a small-area photocathode with a large-area phosphor, the ratio being 2.5 in² to 35 in². Another problem was the development of a simple, cheap window of large area. This window had to satisfy the two opposing requirements of opaqueness to light and transparency to alpha particles. Obtaining a rolled aluminum foil that was hole-free, 35 in² in area, and 0.006 mm thick, presented a major production difficulty. Since the ZnS plastic sheet was still under development, we had to use a deposited phosphor with a separate aluminum-foil window.

In the search for a suitable window material, the scheme that showed the most promise was one in which ZnS crystals were mixed into a cold-setting plastic fluid. The mix was such that the crystals settled to the bottom before hardening took place. When hard, the lower surface of the plastic sheet was sputtered with aluminum by a special process. The final material could be cut to any shape desired and easily fitted in the field.

Careful measurements showed that 12 mg/cm² was the optimum deposited phosphor thickness for maximum response over the range of incident energies expected. This thickness was easy to produce and to control in production.

An exploded view of the counter is shown in Fig. 2. Several features of the counting unit are worth noting:

1. The dynode feed network is mounted around the photomultiplier to reduce the total length of the combination.

2. The position of the photomultiplier tube is adjustable along the axis. This makes it possible to obtain an even response position for the photocathode relative to the reflector.

3. In the ZnS screen a special process was used to bond the ZnS crystals to the surface of the Lucite mount.

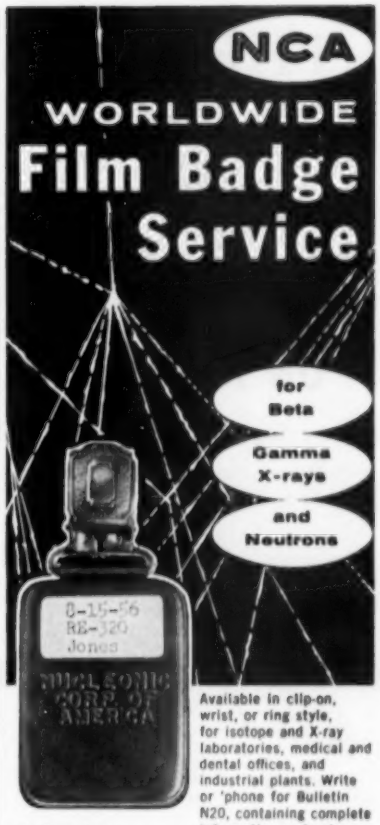
4. The front grill is made of stainless steel with a tensioned piano-wire mesh. Thus, the "lost area" normally taken up by the metal intersections of a punched metal grill is substantially reduced. The entire frame is detachable for decontamination.

5. The parabolic reflector, described in detail below, is novel.

Reflector Development

As a result of investigation of many optical systems a parabolic section is used as a reflector and light concentrator. We used a flying-spot scanning system for the dynamic observation of photomultiplier-reflector combinations.

Figure 3 outlines the system. Modified TV receivers were used as oscilloscopes since they were suitably equipped with scanning generators and video signal chains. Three reflector arrangements were used in the dynamic tests: truncated cone, pyramid, and parabolic section. Based on the evenness of the picture on the second oscilloscope, the parabolic shape was chosen as the best. Also, it was found that



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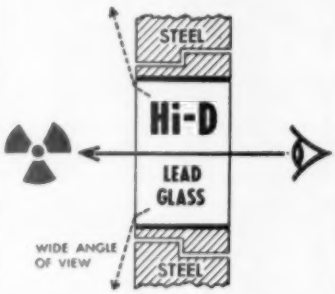

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the best position for the photocathode was not at the principal focus, but a short distance away along the axis.

Matt-white and polished-aluminum surface finishes were investigated. We adopted a reflector of superpure aluminum finished internally with a special hard anodized process that yielded a bright durable surface giving 70% reflection of incident light.

The most important data obtained with this test setup was the ratio of response at the inside edge of the reflector to the response at the center. The parabolic shape gave ~90% of the center response at the maximum usable radius. (This value has since been further improved by use of a new method of bonding magnesium oxide to the reflector surface.)

After a prototype was built based on these preliminary results, the center to inside-edge ratio was checked, using a small collimated alpha source close to the large-area phosphor—it was even better than expected.

Developmental Model

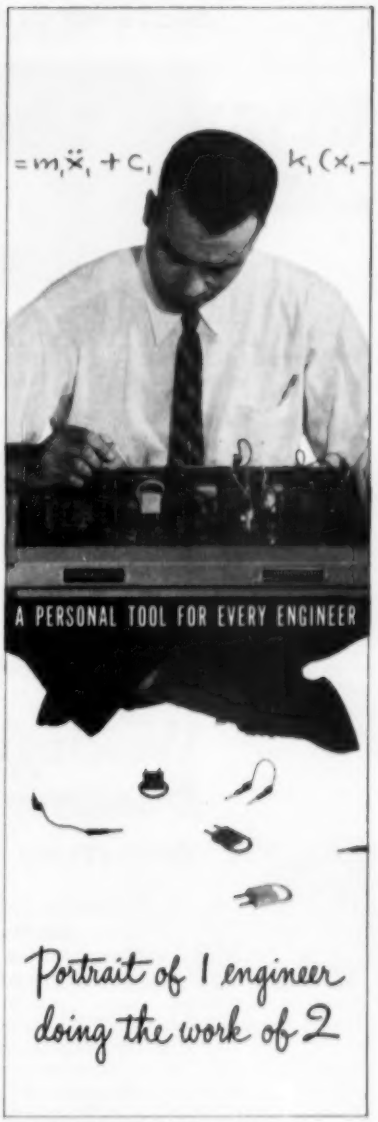
The development model monitor includes a pair of alpha hand counters, both alpha and beta-gamma probes, a pulse amplifier, discriminator, counting-rate circuit, and an amplifier and loudspeaker.

The circuits used represent standard Harwell practice and have a high degree of stability (4). One feature is the economy of using a common power supply and a single feedback pulse amplifier for all the counters.

The monitor indicates whether the maximum permissible level has been reached or exceeded for alpha, beta, and gamma activity on the clothing and alpha activity on the hands. Operation is semiautomatic with adequate alarm and safety circuits. Standard ratemeter indications are provided for alpha, beta, and gamma measurements on clothing. For the very low alpha concentration that constitutes the maximum permissible level, an integrated count is used.

The average plateau length for a complete assembly, including one of the large-area alpha counters, is ~115 volts.

Using one pair of large-area alpha counters it is possible to monitor only one hand at a time. Almost any combination of photomultiplier tubes can be used for the upper and lower counters despite the requirement of similar sensitivity for the two units, since the light produced in the phosphor is strong



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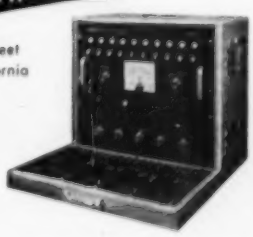

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A Look Ahead

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3. A window material in sheet form that combines the necessary phosphor and light-tight qualities.
4. Reduction of monitoring time.
5. Use of the Kandiah (*5*) design of low-level discriminator to eliminate amplifiers of any sort.
6. Use of large-area photomultiplier tubes to simplify reflector design.
7. New reflector designs that allow both sides of a hand to be monitored in the same housing.
8. Improvements in the geometry of the counter assembly.

BIBLIOGRAPHY

1. N. F. Lansing. The role of engineering in nuclear energy development. TID-5031 (1951)
2. "The Biological Effects of Atomic Radiation" (National Academy of Sciences—National Research Council, Washington, D. C., 1956)
3. K. E. G. Perry, AERE, Harwell, private communication
4. AERE Catalog No. 3–7/12130
5. K. Kandiah, *Proc. Inst. Elec. Engrs., London* **101,** part 2, No. 81 (1954)

Program for Meeting on Radiation Effects on Materials

The following program is sponsored by the Office of Naval Research and Glenn L. Martin Co., March 27–29, 1957, Johns Hopkins University (Shriver Hall), Baltimore, Md. Contact: J. G. Morse, Nuclear Div., Martin Co., Baltimore 3, Md.

Program:

Metals—Defects in Solids (Dienes); Experimental Approaches (Wilson); Metals and Alloys (Billington); Effects on Corrosion and Surface Properties (Simnad)

Nonmetals—Inorganic Dielectric Materials (Smolochowski); Semiconductors (Lark-Horovitz); Organic Substances (Burton); Polymers (Charlesby)

Reactor Components—Cores, Liquid Coolants, Control Rods (Weber); Moderators, Shields, Auxiliary Equipment (Henig)

Copolymerization (Restaino)

Round Table (Dalzell, panel leader)

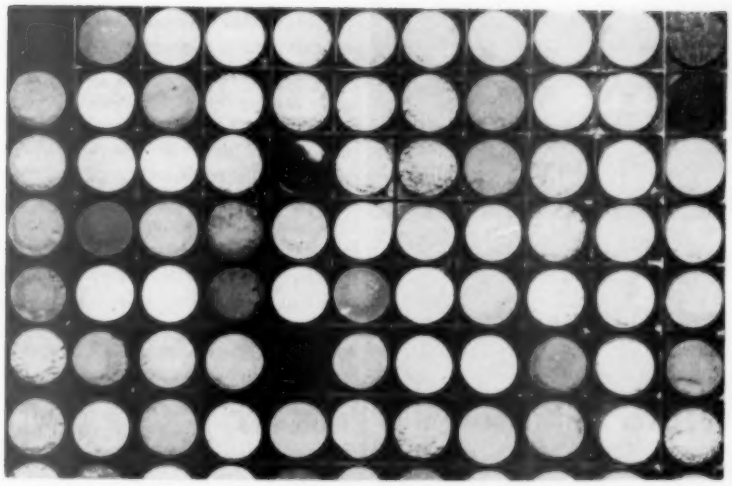

FIG. 1. Powdered U_3O_8-ore samples in cassette. Standards (4.3%, 0.43%, 0.043%, 0.0043% U_3O_8) are placed (counting from top left; letters and numbers give vertical and horizontal positions, respectively) at G9, F8, E7, and D6, respectively. C5 is a blank

Autoradiographic Determination of Radioactivity in Rocks

By ALBERT P. ABRAHAMS
Division of Industrial Hygiene
New York State Department of Labor
New York, N. Y.

A sensitive G-M or scintillation counter is currently used for field assay of radioactive rock samples. However, such equipment has at least two disadvantages:

To suppress background activity effectively, shielding may have to be bulky enough to seriously limit portability. Also, these counters can count only one sample at a time—automatic sample changers are impractical under field conditions.

The autoradiographic method we propose here, in which 110 samples can be simultaneously exposed to the same sheet of film, offers the following advantages:

1. Standards of known U_3O_8 concentration may be exposed to the same film as other unknown rock samples. This eliminates errors due to type or quality of film and development differences. Thus, an absolute calibration is not necessary, and a permanent record is available.

2. Large number of samples may be handled simultaneously. For comparable results, electronic equipment would have to include sample changer, printer, and recorder.

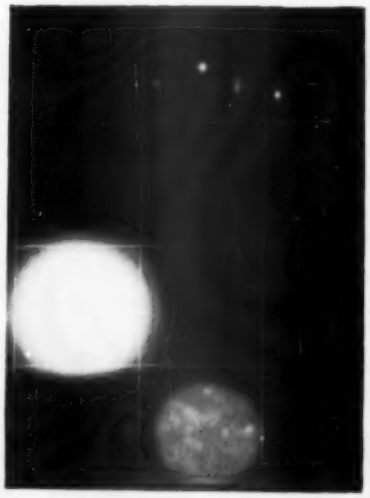

FIG. 2. Autoradiograph of U_3O_8 samples. At bottom left are standards, and at top right are unknowns

3. For low levels of radioactivity, results indicated greater precision with the radiographic method than with the G-M counter. Since G-M counters are generally unshielded in field use, high background rates make it difficult

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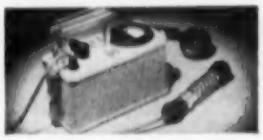

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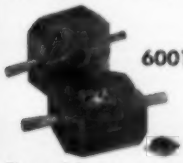

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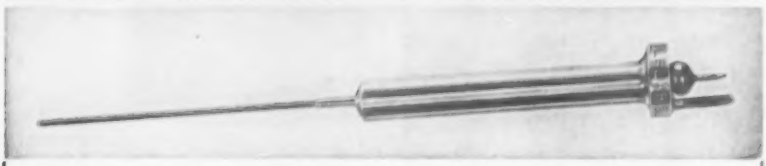

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to obtain reliable results with samples containing low concentrations of radioactive materials.

4. With autoradiography, expense is confined essentially to the cost of developer, fixer, film cassettes, and similar photographic equipment. A darkroom equipped with developing and fixing basins and a densitometer are the only capital investment required.

The accuracy of the autoradiographic method, as described here, is limited by the assumption that all radioactivity is due to U_3O_8. Of course, it is adaptable to monazite or other thorium ores.

Procedure

The rocks are first ground to the consistency of a fine powder. Samples are selected weighing 4–6 gm.

A 14 × 17-in. Du Pont 508 X-ray film is exposed to the samples in a cassette lined to hold 110 samples in 1⅜-in. squares (see Fig. 1). The samples are tamped into cylindrical Lucite containers, 1⅛ in. in diameter and ⅛ in. high.

The film is developed, using standard Kodak X-ray developer and fixer, after a 2–3-week exposure period. The exposure time is varied to find the optimum duration—long enough for low-level activities to be measurable, but not so long as to make the opacity due to highly active samples unreadable on the densitometer.

After drying, the film is ruled into a grid, corresponding to the mapping of the cassette, so that each sample has its own definite area on the film assigned to it (see Fig. 2). These areas are read on an optical densitometer.

The findings were checked by measuring the activities of the samples with a mica-end-window G-M counter and scaler, a type generally favored for field-survey work.

The readings for the standards were plotted on a graph of film darkening vs. concentration of U_3O_8. Curves were fitted from which the radioactivity of the unknowns could be read off, and the percentage of U_3O_8 determined.

Reprints Available

Applying Radiation in Industry (May '56)—$1.25
How Radiation Affects Materials (Sept. '56)—$1.25

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NUCLEAR CALENDAR

March 18–27—National convention IRE, New York; professional group on nuclear science meets 20th (*Waldorf*); exhibits (*Coliseum*). Contact IRE, 1 E. 79 St., NYC.

March 25–27—10th Western Metal Congress & Exposition, Los Angeles (*Ambassador*). Sessions on nondestructive testing in nuclear energy; also isotope tests. Contact W. H. Eisenman, secy., Am. Soc. for Metals, 55 West 42nd St., N. Y., N. Y.

March 27–29—19th annual American Power Conference, Chicago (*Sherman*). Sessions on nuclear power. Contact R. A. Budenholzer, Illinois Tech, 35 W. 33 St., Chicago 16.

March 27–29—Colloquium on radiation effects on materials. (Office of Naval Research, and Glenn L. Martin Co.), Baltimore (*Johns Hopkins Univ.*). Contact Jerome Morse, Martin, Baltimore 3, Md. *See p. 84 for program.*

April 10–12—National nuclear instrumentation conference and exhibit, ISA, Atlanta (*Biltmore*). Contact Fred J. Tabery, 3443 S. Hill St., Los Angeles 7.

April 15–19—7th annual high energy physics conference, National Science Foundation, Rochester, N. Y. Contact Robert Marshak, Rochester U.

April 16–18—Symposium on nondestructive tests in the nuclear energy field (Am. Soc. for Testing Materials jointly with ANS, AIChE and the Society for Non-Destructive Testing), Chicago (*Morrison*). Contact W. J. McGonnagle, Argonne National Laboratory, Lemont, Ill.

April 22–26—Annual meeting American Industrial Hygiene Assn., St. Louis (*Kiel Auditorium*). Radiation sessions 25–26th. Write Rm. 1300, 28 E. Jackson Blvd., Chicago 4.

April 29–May 1—Eighth annual spectroscopy symposium (Am. Assn. of Spectrographers), Chicago (*LaSalle*). Contact T. H. Zink, 4528 Division St., Chicago 51.

May 13–15—Annual meeting, Radiation Research Society, Rochester, N. Y. Symposia on radiation genetics and on radiation chemistry. Contact A. Edelmann, P.O. Box 10901, Pittsburgh 36.

May 14–16—Second annual Industrial Nuclear Technology conference on applied uses of radiation (Armour Research Foundation and NUCLEONICS), Chicago (Museum of Science and Industry). L. Reiffel, ARF, 3440 S. State St., Chicago.

May 28–29—Second reactive metals conference (So. California section AIME), Los Angeles (*Ambassador*). Contact B. S. Mesick, Arthur D. Little Inc., Los Angeles.

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Using radiotracer techniques developed by California Research Corporation, engineers at the Richmond refinery of Standard Oil Company of California are obtaining flow rate measurements with accuracies of 2% to 5%.

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123

A Device for Tensile Tests of Irradiated Metals

By R. E. HUESCHEN and D. C. KAULITZ
Hanford Laboratories Operation
General Electric Co.
Richland, Washington

FIG. 1. Over-all view of apparatus showing optical unit in foreground and removable furnace beyond

THERE HAS LONG been a need for an apparatus to measure tensile properties of irradiated fuel and structural materials at high temperatures. For future reactor development it is essential to know the properties of irradiated materials at operating temperatures and the effects of irradiation on these properties.

We have constructed and tested an apparatus that permits tensile testing of highly radioactive specimens at temperatures up to 800° C (1,475° F). It contains an optical unit capable of observing specimen strain through shielding windows. This unit can measure elongations up to 50% with a 1-in.-long sample, so it is a relatively long-range extensometer.

To protect samples from high-temperature oxidation a vacuum system has been designed as an integral part of the furnace. The furnace can be removed to permit remote handling of samples. Figure 1 shows the system in operating position.

Tensile Unit

Raising and lowering the vacuum furnace for loading of the radioactive specimen requires a testing machine with long tensile columns. It was decided to use a 60,000-lb Baldwin-Lima-Hamilton machine. Its long, heavy columns do not affect the accuracy of the machine's loading system.

Elongation Measurement

After considering and testing three strain-measuring techniques, we decided on a direct optical method. This appears to be best from the standpoint of remote operation. With successful development of such a unit it became possible to design the vacuum furnace and associated equipment.

The other two methods use commercial strain gages or optical gages such as the Tuckerman. Preliminary results showed that they had design limitations plus problems of remote control.

Design of unit. The optical strain-measuring unit was designed in collaboration with the Gaertner Scientific Corp. It has a focal distance of over 24 in. to permit insertion of shielding between optical unit and furnace to protect the operator from radiation. The light from the optical unit travels through 6 in. of lead-glass shielding and the quartz window of the furnace. Along this path reflected gage marks from platinum strips are projected through the shielding to the eyepiece of the optical unit.

The instrument is shown in Figs. 2 and 3. It has a double collimator system in which the upper objective can be moved relative to the lower one by an accurate micrometer screw. The two collimated images of the fiduciary marks are superimposed by a combining system incorporating two penta prisms, one of which is of the combining form. Each penta prism is mounted integrally with its corresponding collimator objective.

The initial separation of the objec-

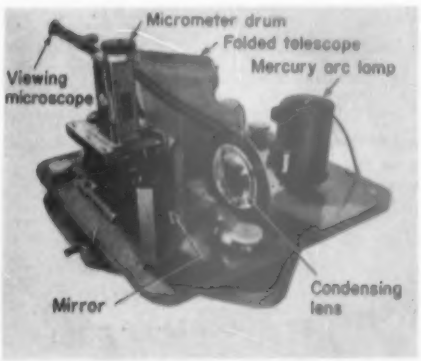

FIG. 2. Optical strain-measuring unit

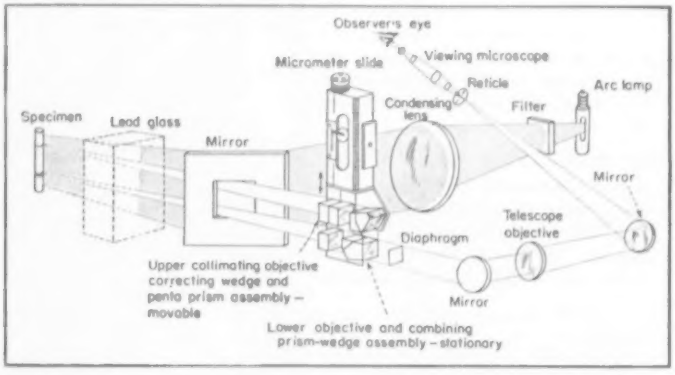

FIG. 3. Diagram of working parts of optical system

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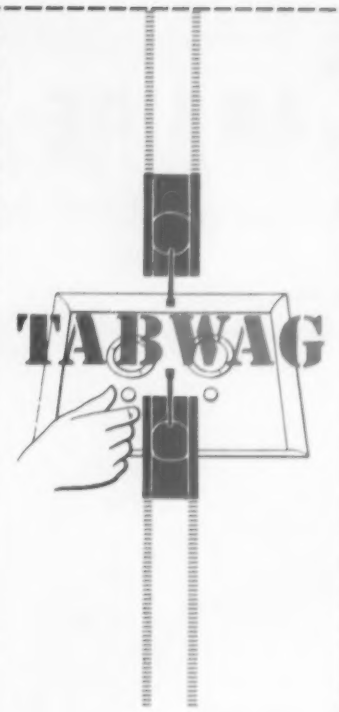

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tives is equal to the specimen gage length of 1 in. At this setting the micrometer scale and drum read zero. The two collimated images (gage marks) are superimposed in the focal plane of a folded telescope and viewed by a microscope. As long as the separation of the two objectives equals the separation of the two gage marks, the images are superimposed. The micrometer-and-objective-prism unit is mounted on a dovetail slide, moved by a knurled screw for focusing.

The movable objective attached to the micrometer screw is made to follow the separation of the gage marks as the specimen stretches. The motion is calibrated to 0.05 mils. Total range of the micrometer motion is 0.5 in. This long range is an important feature; it makes it possible for the unit to measure elongation to failure of many irradiated specimens. For many materials this permits plotting the entire plastic range, which is advantageous in the study of the effects of radiation on materials.

The illumination system of the instrument consists of a high-intensity mercury lamp, condensing lens, and a front-surface mirror to reflect the light along the optical path. The mercury lamp, adapted specifically to fit the instrument, and the condensing lens are adjusted to focus the light beam on the platinum gages.

All components are mounted and aligned on an aluminum base plate equipped with three leveling screws (Fig. 2). The three are simultaneously chain driven from a handknob for elevation control.

The whole instrument rests on a lower base plate with three pads. The leveling screws fit on the pads of the lower plate. Two of the pads have curved grooves in which the leveling screws ride on steel balls. The third screw is a pivot point. The screws are in such positions that the guided movement of the upper plate relative to the lower one rotates the instrument ~6 deg around the viewed object. This permits adjusting the angle of reflection for optimum contrast.

The aluminum plate mounts on a heavy, flat, cast iron plate (Fig. 1). This plate has its own set of three leveling screws and is mounted on a table at the correct height in relation to the sight windows of the vacuum furnace.

Gage Marks

The optical method of measuring elongation requires a gage mark on the specimen. Gage lines were inscribed on polished 0.25 × 0.56-in. platinum strips with a Bierbaum Microcharacter instrument. Each specimen requires two gage strips, one with single lines 0.03 in. apart, and the other with double sets of lines 0.0015 in. apart on 0.03-in. centers.

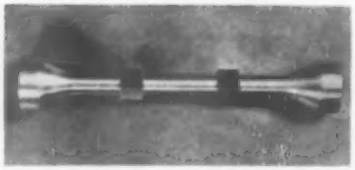

FIG. 4. Specimen ready for testing

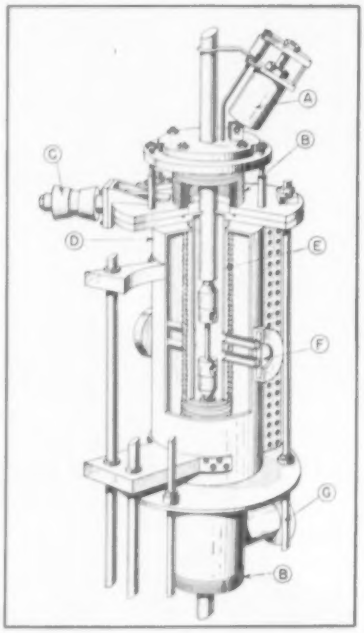

FIG. 5. Isometric view of tensile-testing apparatus shows thermocouple vacuum seal and air cylinder (A), upper and lower bellows (B), vacuum-seal-actuating cylinder (of which there are 3) (C), furnace (D), heating coils (E), viewing windows (F), and vacuum port (G)

Trials showed the necessity of more than one set of lines for maximum viewing intensity. When one set can not be properly focussed, the entire optical unit can be raised or lowered to the next set 0.03 in. away. The lower strip with lines 0.0015 in. apart acts as a vernier. The single line of the upper strip is superimposed between the double lines of the lower strip. With the high magnification of the optical unit one can detect the slightest movement of the single line due to elongation.

Welding fixture. The platinum gage strips are bent and spotwelded to

the specimen with 1-in. separations by means of a special fixture. The specimen is held tightly against the gage strips by a tapered pin. Fixture-and-specimen assembly are held in place by a stationary lower electrode. A specimen ready for testing is shown in Fig. 4. Spotwelding of gage strips to irradiated specimens is done remotely in a multicurie cell.

Vacuum Furnace

The optical method of strain measurement requires a specially designed furnace to maintain uniform temperature distribution throughout the heating chamber. Other requirements are quartz windows to view the gage marks, special seals to maintain the high vacuum necessary to prevent sample oxidation, and remote control for safety of operation with highly radioactive samples. An isometric section of the furnace is shown in Fig. 5.

The upper and lower pull rods are attached to spherical seats in the cross heads of the tensile machine. The furnace proper is supported by a special bracket that is attached to one of the machine columns as shown in Fig. 1. Axial loading of the specimen is assured by isolating the weight of the furnace from the pull rods and by using upper and lower bellows to transmit the motion of the rods to the furnace chamber.

One of the major design problems was to insure that the viewing windows would not induce a thermal gradient along the specimen. It would have been desirable to have two large viewing windows located opposite each other. However, preliminary calculations proved large size to be impossible if specimen-temperature differences of less than $\pm 1°$ C were to be maintained. Heating coils were required in the center of the furnace. It was found necessary to use four small tubes—shown in Fig. 5—so that temperature-gradient limits could be met.

The furnace is designed to operate at a maximum of 800° C with a vacuum of 10^{-5} mm of Hg when clean, dry, and outgassed. Thermocouples are brought out through a vacuum seal actuated by an air cylinder mounted on the top flange of the upper bellows.

The furnace is operated remotely by actuating the three horizontal air cylinders (Fig. 5). This breaks the vacuum seal between the upper bellows and the furnace proper. Then the furnace is lowered on Thomson ball bushings by means of a rack and pinion

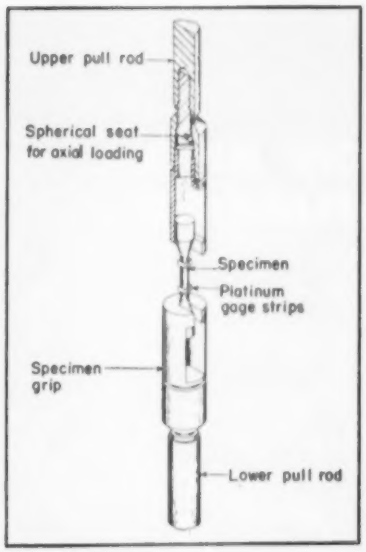

FIG. 6. Grips that hold tensile specimen are remotely loaded after furnace is removed

mounted on the tensile column. After the furnace has been lowered to expose the grips, the tensile specimen is loaded remotely into the grips as shown in Fig. 6. The specimen is remotely rotated in the grips until maximum reflectivity is obtained from the platinum strips when viewed with the optical unit. The furnace is then raised into position for viewing through the quartz windows and the horizontal air cylinders are actuated to effect the vacuum seal.

The furnace is designed to travel upward at half the speed of the upper pull rod. This movement permits use of 0.5-in.-diameter sight tubes, and still the operator can measure 50% elongations with 1-in. specimens. The testing machine and furnace are enclosed in a 6-in.-thick lead-brick cell. Lead-glass windows are located at appropriate positions, and an optically flat lead-glass window is used for transmitting the reflected image of the gage strips to the optical telemicroscope.

Vacuum System

The vacuum system is built around an NRC H-4-P purifying-type oil diffusion pump with an ultimate vacuum of 4×10^{-7} mm of Hg and an NRC-4S mechanical pump. The diffusion pump has a 300-liter/sec speed in the region of 10^{-3} mm of Hg. In the hot, outgassed furnace we achieve the design vacuum of 10^{-5} mm of Hg.

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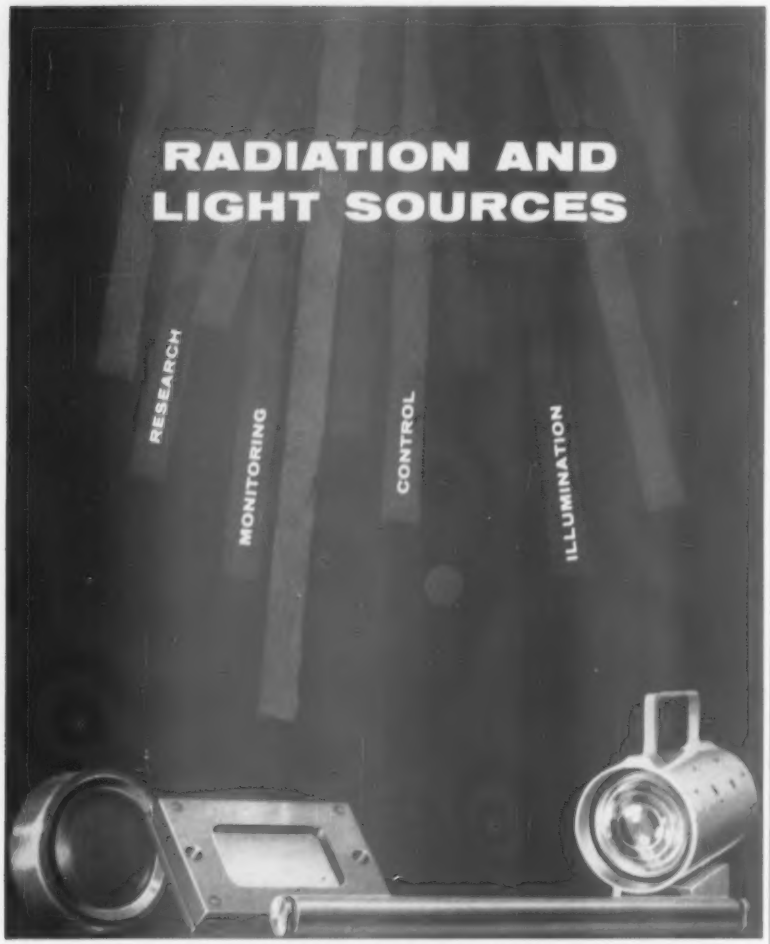

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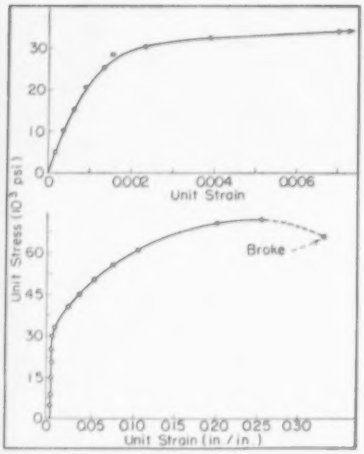

FIG. 7. Stress-strain curves measured with mild steel and 347 stainless

710 NRC ionization gage and a thermocouple gage are installed as close to the furnace as possible. All valves are pneumatically controlled from a single panel.

A 36-in.-long bellows connects the vacuum pumping system to the vacuum port of the tensile furnace. The long bellows is brought through the lead-brick cell and permits the movement necessary to raise and lower the furnace.

Results

The furnace has been calibrated at 300°, 500°, and 700° C (572°, 932°, and 1,292° F) with thermocouples located on the specimen and on the grips. After reaching equilibrium at each temperature the maximum difference between any of the thermocouples was 1° C, and the temperature fluctuation was less than $\pm 1°$ C.

To evaluate the operation and accuracy of the equipment, tensile tests were made at room temperature and above using unirradiated 347 stainless steel and mild steel. Our results were in agreement with those of conventional methods. Some of them are shown in Fig. 7. Figure 7 illustrates the unit's ability to measure a relatively large elongation. The unit has also been used successfully in obtaining stress-strain curves of irradiated specimens.

* * *

The authors wish to thank the Gaertner Scientific Corp. and the L. H. Marshall Co. of Columbus, Ohio for their valuable contributions and assistance in the construction of this equipment. The technical assistance and advice of R. S. Kemper, W. S. Kelly, and E. C. Watts, Hanford Atomic Products Operation, in the operation of the unit is greatly appreciated.

Gamma-Ray Heating in BSR

By F. T. BINFORD
Oak Ridge National Laboratory
Oak Ridge, Tennessee

To determine the rate of gamma heating in aluminum, lead, iron, or copper structures near reactor cores, temperatures of these materials were measured during heating in the gamma field of the Bulk Shielding Reactor (*1*) and during cooling after being removed from the field. The results are valid for engineering design of reactor structures where the gamma spectrum is about the same as that of the BSR.

The problem of determining temperature distribution in structural members in a reactor is a frequent design problem. If the structure is sufficiently near the core to be heated appreciably by the deposition of energy from gamma radiation, it must be cooled to prevent excessive temperatures. Methods of calculating such temperature distributions are well known, given heat-generation rate, physical constants of the material, and a description of the method of heat removal (*2*). But it often is difficult to estimate the heat-generation rate itself.

To determine heat-generation rates in construction materials of the Oak Ridge Research Reactor, experiments were performed using the BSR, which is similar to the ORR in many respects.

Experiment

Figure 1 shows the experimental arrangement and the core loading.

Preliminary tests indicated that heat loss from the surface of the metal samples immersed directly in the water is too high to obtain satisfactory temperature rises. Thus, the small cylindrical test sample was suspended from the thermocouple wires inside a small capsule as shown in Fig. 2.

The experimental procedure consisted of positioning the capsule containing the sample on the center line of the BSR core at a predetermined horizontal distance from the reactor by hanging it from a 10-ft boom. The boom was then rotated through 90 deg to remove the capsule from the vicinity of the core. The reactor was started up, and when the proper steady-state power level was achieved, the capsule was swung back into position and the temperature recorded as a function of time. After a suitable temperature rise occurred, the capsule again was swung away from the reactor and the cooling curve was recorded.

The measurements with the lead sample were made at the surface of the reactor and at distances from the core of 3, 6, and 9 in. For aluminum and iron, the heat generated in the samples was lower and it was not possible at the power level available to obtain

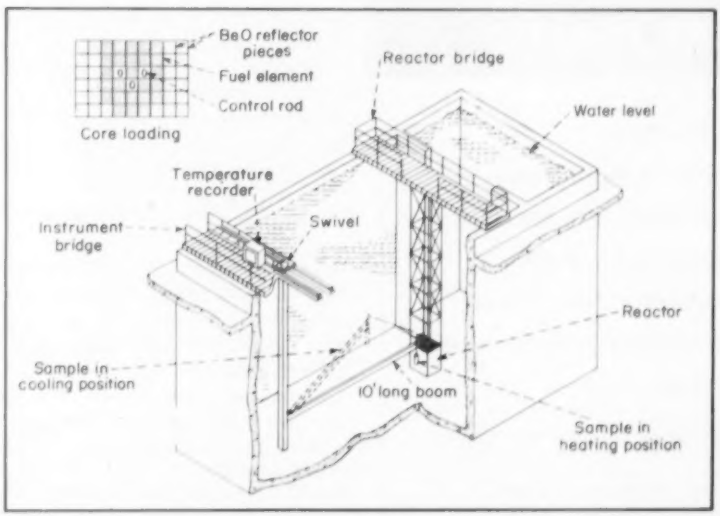

FIG. 1. For each experimental run, sample was placed in gamma field of BSR while it operated at constant power level. When suitable temperature change was indicated on recording millivoltmeter connected to thermocouple embedded in sample, the sample was removed from gamma field and rate of cooling was observed. Water temperature in 20 × 20 × 40-ft pool remained constant at ~90° F

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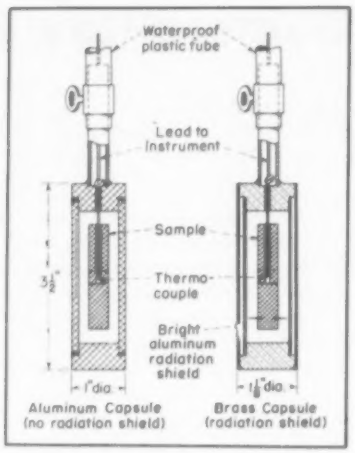

FIG. 2. Irradiation capsules. Three needles kept samples from touching capsule wall, which stays at same temperature as surrounding water. This eliminated convection currents that might cause changes in heat-transfer coefficient. There was no significant difference in results between two capsule designs whether vacuum was maintained or natural circulation was permitted through thermocouple tube

reliable results at distances greater than 4 in. from the surface of the core.

Analytical Method

If a small solid body has thermal conductivity k, and if, starting at some time $t = 0$, heat is generated in it uniformly at a constant rate Q (energy/unit time/unit volume), and if L is a characteristic dimension of the body, and if the quantity $QL^2/2k$ is small, then the temperature of the body can be considered to be virtually independent of position in the body. Further, if heat is lost from the body only by conduction at the surface, and if the rate of loss of heat is proportional to the temperature difference between the body and its surroundings, then the net change in heat content can be written

$$V\rho C \frac{d\theta(t)}{dt} = QV - hS\theta(t) \qquad (1)$$

where the temperature of the surroundings has been arbitrarily chosen to be zero, and V = volume of the body, C = specific heat, ρ = density, $\theta(t)$ = temperature of the body at time t, h = heat-transfer coefficient, S = surface effective in heat removal. If the initial temperature of the body is zero, temperature at time t is

$$\theta(t) = \frac{Q}{\mu}(1 - e^{-\lambda t}) \qquad (2)$$

where for convenience we have set $\mu = hS/V$ and $\lambda = hS/C\rho V$, whence

$$\mu = \rho C\lambda \qquad (3)$$

If the same body has initial temperature θ_0, with no heat generation the net change in heat content becomes

$$V\rho C \frac{d\theta(t)}{dt} = -hS\theta(t) \qquad (4)$$

and the temperature at time t is

$$\theta(t) = \theta_0 e^{-\lambda t} \qquad (5)$$

where the value of λ in Eq. 5 is the same as the value of λ in Eq. 2.

Thus if the body is heated to a temperature θ_0 and then the internal heat source is removed and the body allowed to cool, the value of λ can be found from a semilog plot of the cooling curve. Using the value of λ and the known values of ρ and C, the constant μ can be computed. Once these constants are known, substituting some known pair of values of t and $\theta(t)$ into Eq. 2, the heating equation, yields Q.

Advantages of the method. Provided that these assumptions are valid, this method of determining the heat generation rate has two main advantages: (a) the only physical constants that it is necessary to know are the sample density and its specific heat; and (b) by altering either the heat-transfer surface, S, or the heat-transfer coefficient, h, it is possible to adjust the rate of temperature rise to a convenient level without the necessity of knowing either absolutely.

Disadvantages of the method. The obvious disadvantages include the fact that both k, the conductivity, and C, the specific heat, vary with temperature. Generally, these variations can be neglected if the proper temperature range is used. For example, for aluminum the value of C increases about 8% between 0° and 100° C, while the value of k remains virtually constant over the same range. In these experiments both C and k are assumed constant.

The variation of h with temperature depends on the conditions at the surface, and if, for example, the surface of the body is kept in contact with water and the body is permitted to become quite hot, thermal convection currents will be set up that will materially affect the value of h. As is shown, this problem does not arise here.

Results

Semilog plots of typical cooling curves obtained are shown in Fig. 3. Several temperatures were chosen from each heating curve, and, using the corresponding values of λ taken from the cooling curves, Q was calculated.

To check the accuracy of these values

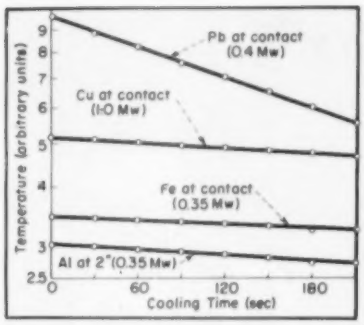

FIG. 3. Typical cooling curves. Values of λ were determined from these curves, and corresponding values of μ were calculated using Eq. 3, with Pb, Al, Fe, and Cu assumed to have C = 0.032, 0.23, 0.115, and 0.094 cal/gm/° C, respectively, and ρ = 11.3, 2.7, 7.87, and 8.94 gm/cm³, respectively

and to determine whether the heat-loss term was indeed proportional to the difference in temperature between the sample and its surroundings, each of the heating curves was reconstructed using the calculated value of Q and the corresponding value of λ found from the cooling curve. In every case the calculated heating curve was an accurate fit to the experimental curve; several typical fits are shown in Fig. 4.

The averages of the numerical results are shown in the table and Fig. 5.

Significance

The appropriateness of applying these data to design problems depends on an understanding of the conditions of the experiments.

Heat-transfer mechanism. As is shown theoretically, the character of

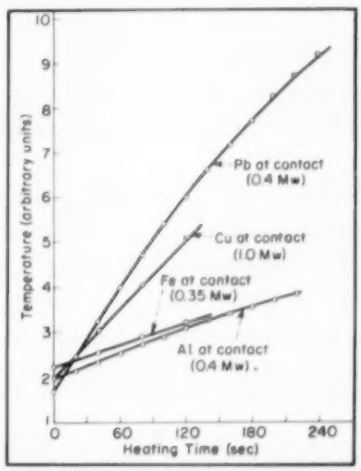
Temperature (arbitrary units)
Heating Time (sec)
Pb at contact (0.4 Mw)
Cu at contact (1.0 Mw)
Fe at contact (0.35 Mw)
Al at contact (0.4 Mw)

FIG. 4. Typical heating curves showing fit of cooling data. Solid lines are experimental curves; points are values of $\theta(t)$ from Eq. 2 using calculated values of Q and μ and the experimental values of λ

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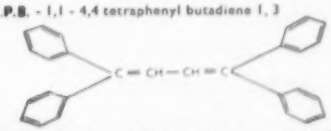

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Average Values of Heat Generation

Material	*Distance from reactor face (in.)*	*Avg. heat generation (watts/gm/Mw)*
Lead	0	0.285
Lead	3	0.150
Lead	6	0.077
Lead	9	0.037
Aluminum	0	0.188
Aluminum	2	0.113
Aluminum	4	0.064
Iron	0	0.233
Iron	2	0.149
Iron	4	0.090
Cu	0	0.197

the procedure used here is such that it is not necessary to know the actual heat-transfer mechanism beyond the fact that for each determination it depends only on the first power of the temperature of the sample. This is verified by the shape of the curves.

Radiation losses. Heat losses by ordinary thermal radiation, which vary as the fourth power of the surface-temperature difference, are kept small by restricting the temperature to which the sample is permitted to rise. That these losses actually are negligible is substantiated by the fact that using the radiation shield in some of the experiments caused no observable change in the results.

Conduction losses. The rate of heat transfer varied from run to run, as evidenced by variation in the values of λ. Most of the heat loss occurred due to conduction through the thermocouple wires and phonograph needles to the wall of the capsule and thence to the pool water, it is believed.

Sample thickness. It also should be pointed out that in these measurements the heat generation obtained is an average over the volume of the sample and

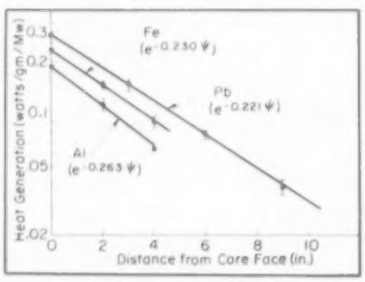
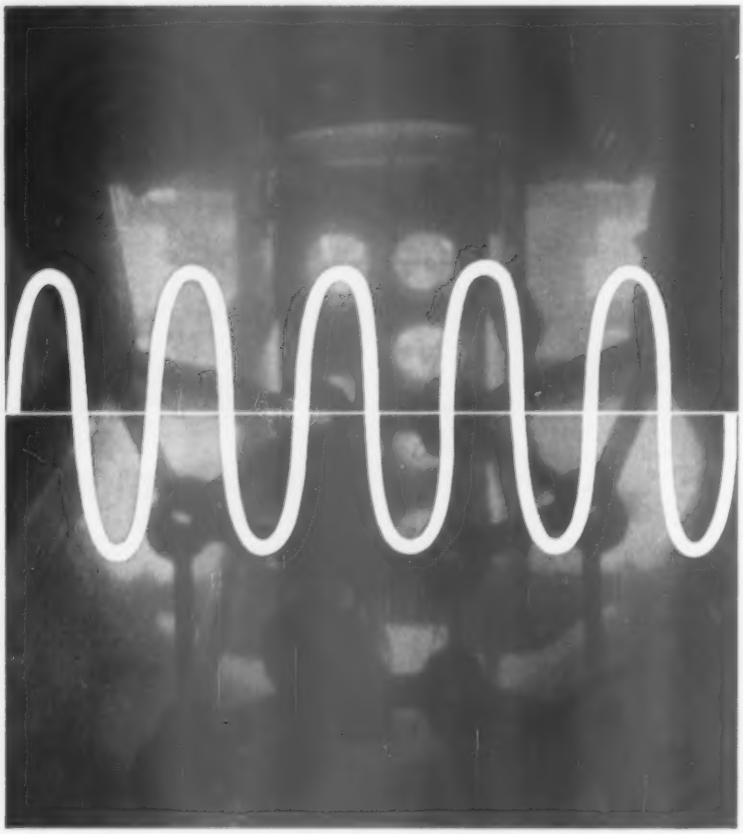


FIG. 5. Gamma heat-generation rates in various metals as functions of distance in water from the BSR face; reasonably straight lines are obtained. Relaxation lengths are 4.5 in. for Pb, 4.3 in. for Fe, and 3.8 in. for Al



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will be affected materially by the thickness of the sample. Lower results would be obtained for thicker samples.

Geometry and environment. In using the present results to estimate heating in large structural members or for cases where the sample does not lie on the center line, both the geometric changes and the effect of the presence of large quantities of other material must be taken into consideration.

To facilitate the handling of the geometric variation due to a change of orientation, the solid angles subtended by the core at the positions used are as follows: when distance from core is 0 in. solid angle is 2π; 3 in., 1.44π; 6 in., 1.02π; 9 in., 0.72π.

Spectrum. The strong energy dependence of the absorption coefficient for these materials is well known (*3*). Thus, changes in the gamma energy spectrum result in corresponding changes in the heat-generation rates. Generally, a given energy flux is more effective in producing heat in a thin slab of absorber if it is carried by many low-energy photons rather than by fewer high-energy photons. For this reason, these results are valid only in cases where the gamma spectrum is approximately that of the BSR. The BSR spectrum has been measured (*4*); the energy-flux distribution is displaced toward the higher energies as the distance (in water) from the reactor is increased. But very little change in spectrum is noted over the short distances of these experiments.

Other workers (*5, 6*) have reported results obtained by the measurement of static temperatures in various locations in the MTR and in the LITR. In view of the probable differences in the energy spectrum because of the presence of beryllium and graphite surrounding the positions in which these measurements were made, it is not possible to compare the results directly.

* * *

The author acknowledges the assistance of J. T. Howe and E. S. Bettis and of the members of the operation staff of the Bulk Shielding Facility who made these investigations possible.

BIBLIOGRAPHY

1. H. S. Carslaw, J. C. Jaeger, "Conduction of Heat in Solids" (Oxford Press, 1947)
2. W. M. Breazeale, NUCLEONICS **10,** No. 11, 56 (1952)
3. W. S. Snyder, J. L. Powell, ORNL-421, Suppl. 2 (1949)
4. F. C. Maienschein, T. A. Love, NUCLEONICS **12,** Nos. 5, 6 (1954)
5. C. H. Hogg, Gamma Heating Measurements in the MTR, IDO-16093 (1953)
6. W. F. Witzig, Experiments in the Materials Testing Reactor Gamma Heating, WAPD-79 (1953)

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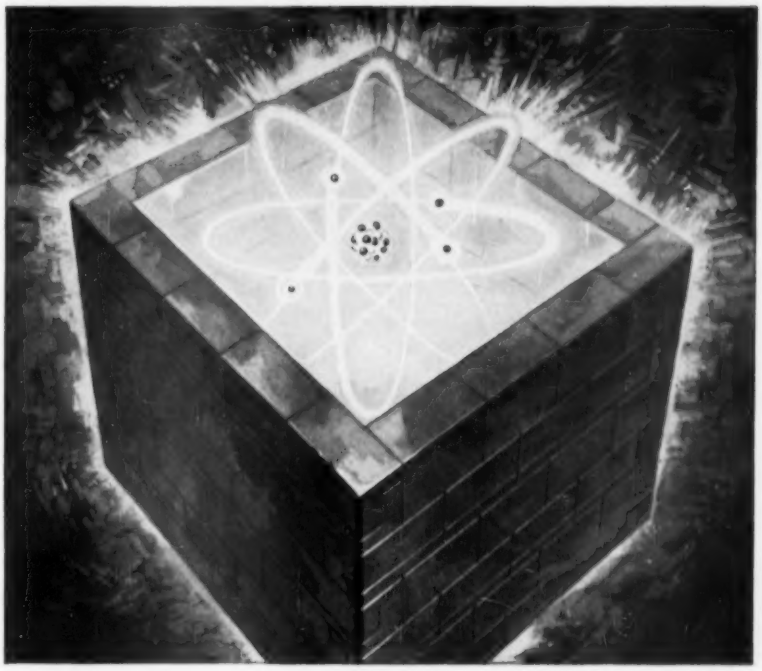

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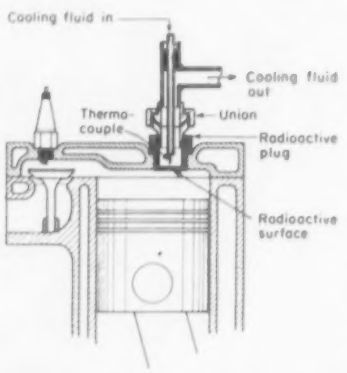
A plug with a radioactive surface is inserted into the engine as shown in the figure. Deposits on the surface reduce the counting rate observed in a standard jig, and the decrease in counting rate indicates the amount of deposit.



Three different isotopes have been used, and they give the experimenter three different ranges of sensitivity. With S^{35} (87 days, 167-kev betas) a 1% change in counting rate corresponds to 0.05 mg/cm² of deposit. With Co^{60} (5.2 years, 310-kev betas) sensitivity is 0.2 mg/cm² per 1% change, and with Ni^{63} (85 years, 67-kev betas) it is 0.01 mg/cm² per 1% change.

The S^{35} surface is formed by depositing sulfur either from a solution in mineral oil or from a dilute solution of ammonium sulfide. A 0.1-μc deposit gives a convenient counting rate of 200–300 cps. With an electroplated protective coating of inactive nickel, the plugs can be polished and reused repeatedly. Co^{60} and Ni^{63} surfaces are prepared by electroplating. These are also overplated with inactive nickel.

As shown in the figure, the plugs have separate cooling channels. The engine is run up to temperature with a dummy plug while the initial counting rate for the active plug is determined. Three hours of operation with the active plug is enough to determine combustion-chamber deposits. Runs up to 8 hours long are used for induction-system tests. For carbonaceous deposits, absorption curves made with polystyrene or cellophane are accurate calibration. With more complex deposits, calibration is estimated from absorptions of pure materials.

The tests have satisfactorily determined the effect of running conditions and gasoline components on deposit rates, and they have given results that are substantially in agreement with their more cumbersome predecessors.

All of the pre-beta-gage methods were awkward and lengthy. There were three of them: (1) dissolving, drying, and weighing the deposit, (2) weighing engine parts before and after, (3) using secondary indices such as octane requirements.

Cobalt Colossus Is Open at Oak Ridge

The world's biggest Co^{60} irradiation facility—85,000–300,000 curies—has been placed in operation at Oak Ridge National Laboratory. It is designed to make use of the radiocobalt awaiting shipment at the laboratory. The amount in storage is expected to be within the above limits at all times.

The irradiation volume is a 10.5 × 10.5 × 12-in. space at the bottom of a plug that can be raised for insertion of samples and lowered for irradiations. Currently there are no provisions for circulation loops in the facility, but the plug does have two tubes that can be used for electrical connections to instruments.

Scintillator Damage—Future Dosimeter?

Scintillating solutions may offer a new means for high-dose dosimetry. In preliminary experiments at Argonne National Laboratory, I. B. Berlman has found that when diphenyloxazole in xylene is exposed to 1–6 Megarep of Co^{60} gammas, its efficiency as a scintillator is reduced.† The height of the half-maximum point

* J. G. Mingle, H. W. Sigworth, B. A. Fries, *SAE Trans.* **64**, 577 (1956) (U. S. Patent 2,660,678)

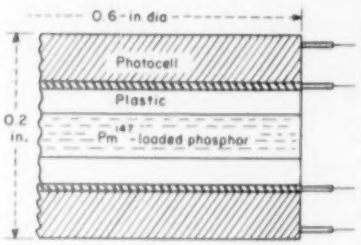
† I. B. Berlman, ANL-5596 (July, 1956).

of the leading edge of the Compton-recoil peak was used as a measure of luminescent efficiency.

When light output from further exposure to Co^{60} gammas is plotted against dose on semilog paper, a straight line results. The effect shows no recovery with time. Dosimetry based on the method would consist of irradiating a vial of solution with the irradiated sample and then measuring the light output excited by Co^{60} gammas with a multichannel analyzer.

Berlman attributes the effect to destruction of the scintillator, increased absorption in the solution, and some undetermined quenching effect in the solution. These conclusions have been drawn from tests made by irradiating prepared solutions, irradiating the components and then making the solution, and irradiating only one component before making the solution.

Tiny Pm^{147} Battery Uses New Principle Beta particles from promethium-147 excite a phosphor, and a photocell transforms the light into electrical energy in a new type of nuclear battery recently demonstrated by the Walter Kidde Nuclear Laboratories and the Elgin Watch Co., its developers. Unlike other types of nuclear batteries (NU, Nov. '55, p. 129, and Dec. '56, p. 71) this one delivers a comparatively high current at a low potential.



The present model of the battery uses 4½ curies of the isotope and delivers 20 μamp at ~1 volt. It is essentially a constant-current source with an output that decays with the half-life of the radioactivity—2.6 yr.

As shown in the sketch, Pm^{147} is embedded in a CdS phosphor. Plastic windows between phosphor and photocell are thick enough to stop the weak betas (223 kev) and prevent radiation damage to the cell. The photocells can be made small or large and connected in series or parallel combinations

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Applied Radiation (cont.)

to provide electrical characteristics suitable for different purposes.

Shielding problems are small since Pm^{147} has no primary gammas. A $\frac{1}{16}$-in. dense-metal case stops the bremsstrahlung that are excited by the beta particles. The shielded battery is 0.2 in. thick and 0.6 in. in diameter.

An advantage of the cell is relative temperature independence. It will operate with increased efficiency at temperatures down to −200° F and with about 70% of room-temperature efficiency at the boiling point of water.

The cost is essentially the cost of the radioactive isotope. Currently that is ~$500/curie, but the developers predict that when the new isotopes-separation plant is in operation at Oak Ridge the battery will cost $2–3.

New York Area Gets Service γ Facility The New York area has its first privately owned gamma irradiation facility intended for public use. Radiation Applications, Inc., has announced opening of their installation in Long Island City. A 1,350-curie Co^{60} source is available to industry on a regular service basis. The company will perform irradiations for their customers or conduct entire research and development programs on a contract basis.

Prices for irradiation exposures are $8/hr during the day and $2/hr at night (5 p.m. to 9 a.m.), and $64/day for continuous 24-hr use. Handling charges are $2.50 per operation by day and $10 at night. Supervision of experiments costs $7.50/hr by day and $12.50/hr at night.

The movable-pig installation is patterned after the one at Stevens Institute of Technology (NU, Nov. '56, p. 119). The cobalt is in four stainless-steel-clad plates mounted on a plunger so that they can be lowered over a container in the center of the irradiation volume. Maximum dose rate available is ~500,000 r/hr in a 2-in. square cylinder 13½ in. high. The minimum dose in the irradiation volume when no absorbers are present is ~40,000 r/hr at the corners. Dimensions of the shielded volume into which the source is lowered for exposures are 17.5 × 17.5 × 36 in. Access holes are available for flow experiments.

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TECHNICAL ADVANCES

Fluidized-Bed Reactor Cores

A new reactor concept, of which there are so many that the nuclear engineering field may be said to be suffering an embarrassment of riches, is being explored at Glenn L. Martin's Nuclear Division. It involves having the fuel in the form of small particles circulating in a "bed" at the base of the (vertical) pipe carrying the liquid stream. In the offing are such advantages as uniform temperature distribution, burnup uniform and independent of power distribution, ease of fission-product removal, ease of fuel fabrication and reprocessing, and low fuel holdup as compared with circulating-fuel homogeneous reactors.

What is a fluidized bed? A fluidized bed is a collection of solid particles which circulate in a confined region as the result of the vertical flow of fluid past the particles. Such fluidized beds with gas as the fluidizing medium have been used by the petroleum industry since the early 1940's to facilitate chemical reactions. For example carbonized catalyst particles can be regenerated most rapidly by passing hot air past the particles at a velocity high enough to keep the particles lifted off the bottom of the reaction vessel.

Actually the bed is in a fluidized state only over a finite range of fluid velocities. At zero fluid velocity the bed is in a static state with the particles lumped at the bottom of the vessel. As velocity increases the bed becomes semiliquid, rather like quicksand; this state is characterized by a pressure drop that increases with velocity. Finally a velocity is reached beyond which the pressure drop stays constant. Further increase in flow velocity causes the bed to increase in volume—the particles are lifted off the bottom of the vessel and circulate in the region of the bed. The bed surface is well defined even with relatively large bed expansions; deterioration of the bed takes place only when fluid velocity exceeds the "terminal" velocity (that velocity which bed particles would attain in free fall through the fluid).

Application to reactors. The idea, then, is to make up a fluidized critical system. The fuel would be in the form of small particles of fissionable material, with or without a protective clad. Moderation would be provided by the fluidizing liquid (light or heavy water or an organic). Fast systems with liquid-metal fluidization are also conceivable. Heat removal could be by the fluidizing fluid itself or by independent heat-transfer loops penetrating into the fluidized region.

Since the fluidized region is characterized by a rapid and independent circulation of the particles the entire bed will be essentially at one temperature. By the same token burnup will be uniform among all the particles since they "sample" all regions of the bed in the course of their circulation. A striking feature is the high rate of heat removal from the fuel particles—of the order of a few thousand kilowatts per cubic foot—thanks to the very high effective surface area presented by the many small particles. However actual heat removal from the core can depend upon the liquid velocity required to maintain fluidization, which may be limited to $\sim$1 fps. The small particle size offers another potential advantage: a large fraction of the fission products will recoil or diffuse out through the surface of the fuel particles. Fabrication costs should be minimal since the fuel is in a particularly simple form.

Control of fluidized-bed reactors promises to be simple. Ordinary control rods could be used, but might be dispensed with in favor of operation under conditions that would be self-regulating. (The bed can be designed so that the critical mass is independent of reasonable fluctuations in bed height.) Scramming can be accomplished by cutting off fluid flow, because the collapsed bed can be designed to be subcritical.

What remains to be done? Clearly the entire study is in a very early stage. The properties of liquid fluidized beds are very little understood, most chemical engineering applications having involved a gaseous medium. Heat-transfer rates, particle erosion, and bed stability need to be studied a lot more. Then would come further studies of the nuclear feasibility designed to make an interesting reactor concept into a useful one.

* * *

Based on a paper presented at the Winter meeting of the American Nuclear Society by C. C. Silverstein, Nuclear Division, Glenn L. Martin Co.

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BOOKS

Nuclear Reactors for Research

By CLIFFORD K. BECK (D. Van Nostrand Co., Inc., Princeton, N. J., 1957, 352 pages, $7.50).

Reviewed by WILLIAM BREAZEALE, Atomic Energy Div., The Babcock & Wilcox Co., Lynchburg, Va.

The "Proceedings of the Geneva Conference on the Peaceful Uses of Atomic Energy" contain, among other subjects, descriptions of most of the unclassified reactor projects in the world. This material is not copyrighted. From these proceedings, Dr. Beck has done an excellent job in assembling and editing the papers dealing with construction, operation, and use of research reactors. Van Nostrand has published these edited papers in a single volume.

Last summer the publishers offered the authors of the various papers the opportunity of bringing their articles up-to-date. Some papers show appreciable editing, either by the author or the editor, while others appear to be little changed from their original form.

Because of the method by which it was assembled, the material does not form a really coherent book on research reactors. It is a collection of papers—nothing more or less. For example, the book opens with L. Kowarski's paper on research reactor types in which their various features are compared in a very understandable fashion, but the only analytical discussion of research reactor design is found much later in a few brief paragraphs at the beginning of A. M. Weinberg's paper on the MTR. Again, the subject of reactor control is touched on here and there in several of the papers dealing with different reactor types, but there is no unified, separate discussion of this subject.

The main topics covered are the following: After Kowarski's paper, one finds a chapter on uses of research reactors. Essentially it consists of a paper by A. W. McReynolds, one by A. H. Snell, and one by E. Bretesher, *et al.* The physics section of the chapter deals with recent research in some detail, and among other things serves to bring material in D. J. Hughes' book up-to-date. The section on chemical research is more abbreviated, though authoritatively written. Engineering research and biological research are covered in a page each. Incidentally, as a result of the juxtaposition of two papers written in entirely different styles, the reader is mildly startled by the sudden transition in the middle of the chapter from McReynold's formal presentation to Snell's chatty conversation.

The papers that make up the rest of the book are devoted primarily to descriptions of various research reactor installations, although much material on reactor uses is found scattered through these chapters. Natural uranium designs are covered in the third chapter, heavy water reactors in the fourth, the homogeneous (water boiler) type in the fifth, and various installations using MTR-type fuel elements in the sixth.

Somewhat oddly, the U.S.S.R. reactors (with one exception) are grouped in a chapter of their own instead of being placed with corresponding types developed in other countries.

A brief but interesting chapter describing two low-power experimental fast reactors (really critical assemblies) built in England concludes the book. These were constructed for the purpose of studying the neutron physics of a fast power reactor. Some of the early experimental results are given along with the descriptions of the reactors.

One peculiar feature of this volume that attracted the reviewer's attention is the absence of cost data. In the case of at least one paper this information was bodily removed by the editor or publisher.

Die Technischen Anwendungen der Radioaktivitaet

By E. BRODA and T. SCHOENFELD (VEB Verlag Technik Berlin, Porta-Verlag Muenchen, 1956, 313 pages).

Reviewed by HENRY H. HAUSNER, Nuclear Engineering Div., Penn-Texas Corp., New York, N. Y.

This is truly an "international" book on the industrial applications of radioactivity. The book was written in Vienna, Austria, during the time that this city was occupied by four occupation army forces, and it seems that the authors had all the references at their disposal to permit them to write such an excellent review book.

There are more than 1,500 references discussed in the book, among which are more than 280 from the U.S.S.R., which makes it even more interesting for the American reader.

The book is written in easily understandable German, probably because the authors for many years spoke only English—an experience that probably shortened their German sentences. Dr. Broda was active for many years at the Universities of Cambridge and Edinburgh, and Dr. Schoenfeld was a private in the U. S. Army during the war years.

The book is divided into 13 chapters and covers fundamentals of radioactivity, measurements, preparation of tracer elements, and fundamentals of tracer metals in engineering. More extensive chapters cover the tracer technique in chemical engineering and metallurgy, and other chapters are devoted to the application of radioactive materials in the paper, silicate, plastic, pharmaceutical, food, and other industries. The importance of radioactive tracers in agriculture is also well covered. The effects of irradiation on the physical properties of solids and gases and the reactions due to these effects are extensively discussed.

A name index, which would make the book more valuable, is missing. However, the extensive subject index is very carefully prepared.

BOOKS RECEIVED

The New World of the Atom, by James Stokley (Ives Washburn, Inc., New York, 1957, xvi + 288 pages, $5.50). (*To be reviewed.*)

Notes on Atomic Energy for Medical Officers, by The Royal Naval Medical School (Philosophical Library, Inc., New York, 1956, v + 168 pages, $4.75). This book was prepared for defense officers concerned with the effects of nuclear warfare. Included are sections on nuclear physics, radiobiology, nuclear explosions, instrumentation, military hazards, treatment of casualties, and radiation protection.

Radio Telemetry, 2nd ed., by Myron H. Nichols and Lawrence L. Rauch (John Wiley & Sons, Inc., New York, 1956, 461 pages, $12.00). Methods, foundations, and techniques of telemetering are the scope of this book. Various methods of multiplexing, modulation, and instrumentation are covered in addition to complete systems and data reduction.

Elements of Gasdynamics, by H. W. Liepmann and A. Roshko (John Wiley & Sons, Inc., New York, 1957, xv + 439 pages, $11.00). Although intended mainly for students in aeronautics, the authors believe this book should be useful to others in the field of aerodynamics of compressible fluids. Fundamentals are emphasized with only enough discussion of applications to illustrate theory.

Stress Corrosion Cracking and Embrittlement, edited by William D. Robertson (John Wiley & Sons, Inc., New York, 1957, 202 pages, $7.50). This book is based on a symposium held by the Corrosion Division of the Electrochemical Society in Boston, Oct. '54. Major research developments of the past twelve years are presented, including the experimental and theoretical aspects of structural metallurgy.

Applied Electrical Measurements, by Isaac F. Kinnard (John Wiley & Sons, Inc., New York, 1956, 417 pages, $15.00). This book covers theory of measurements, measurement of electrical quantities, and measurement of nonelectrical quantities with electrical means. It is one of a series by General Electric authors.

Modern Instruments in Chemical Analysis, by F. M. Biffen and W. Seaman (McGraw-Hill Book Co., Inc., New York, 1956, ix + 334 pages, $7.50). Principles of operation, methods, uses, and commercial sources are given for instruments used in quantitative and qualitative analysis. A chapter is included on radioactivity and related instrumentation.

Arcs in Inert Atmospheres and Vacuum, ed. by W. E. Kuhn (John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., London, 1956, viii + 188 pages, $7.50). This book consists of papers presented at a symposium held by the Electrochemical Society in San Francisco, April 30, 1956. The papers are in four groups: status of high-current arc technology, fundamentals, furnace design and operation, and chemical applications. Of particular interest is a paper by H. Gruber on German developments in vacuum arc melting of titanium and zirconium.

Elementary Wave Mechanics, 2nd ed., by W. Heitler (Oxford University Press, New York, 1956, viii + 193 pages, $2.90). One of the lucid theo-

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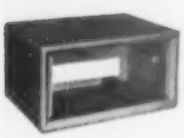

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Some Effects of Ionizing Radiation on Human Beings (TID-5358). This report on the Marshallese and Americans exposed to fallout following the detonation of a thermonuclear device, March 1, 1954, was edited by E. P. Cronkite, V. P. Bond, and C. L. Dunham for the AEC. 106 p. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $1.25.*

Die Reaktoren der Welt. This tabulation of reactors is reprinted from *Die Atomwirtschaft.* Over 300 reactors are listed under three headings: reactors in service, research reactors planned and under construction, and power reactors planned and under construction. 48 p. *Verlag Handelsblatt GmbH., Dusseldorf, Germany, $1.15.*

Nuclear Reactor Data, 2nd ed. This revised edition tabulates information on 142 existing or definitely planned reactors and additional reactors for which few details are available. Reactors are classified by moderator. *Reactor Booklet, Raytheon Manufacturing Co., Waltham 54, Mass., $1.00.*

Annals of Physics. This new monthly journal will contain original articles on research in any branch of physics. Editor is P. M. Morse; assistant editors are B. T. Feld, H. Feshbach, and R. Wilson. Volume 1, number 1 is scheduled for April '57. *Academic Press, Inc., 111 Fifth Ave., New York 3, N. Y.; vol. 1, 3 issues, $8.00; vol. 2, 6 issues, $14.00.*

Adaptation to Ionizing Radiation (PB121352). A. T. Krebs and J. B. Storer, Army Medical Research Laboratory, concluded from literature survey and experimental studies that adaptation is possible in certain tissues. 19 p. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $0.50.*

Atomic Energy in Canada. This booklet is an enlarged and revised version of a booklet issued during the Geneva conference. It contains 98 photo-

graphs and 53 diagrams, including maps of mining areas, Chalk River, Canada-India reactor near Bombay, and Deep River. General and technical descriptions are given of the NRX, NRU, NPD, ZEEP, PTR, and CIR reactors. A section gives the ABC's of atomic energy. 96 p. *Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada, $1.00.*

Energy Loss and Range of Electrons and Positrons (NBS Circular 577). This tabulation, made by A. T. Nelms, contains data on the mean energy loss due to ionization excitation, and on the mean range derived from the mean energy loss. The range of validity is somewhat limited since corrections, such as density effect, were not included. 30 p. *Government Printing Office, Washington 25, D. C., $0.30.*

Tables of Chemical Kinetics, Homogeneous Reactions (Circular 510, Suppl. 1). The supplement, a compilation of rates and rate constants, includes new tables, and additions and revisions for existing tables. 472 p. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $3.25.*

Principles of Laboratory Temperature Control, Electronic Relays, Thermistor Operated Temperature Control (PB 121120). 55 p. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $1.50.*

Handbook of Commercial, Financial and Information Services, 5th ed. This guide describes 776 organizations that supply specialized information on a contract or demand basis. 240 p. *Special Libraries Association, 31 E. 10 St., New York 3, N. Y., $5.00.*

Standard X-Ray Diffraction Powder Patterns (NBS Circular 539). This Bureau of Standards circular presents 44 standard patterns, 23 of which replace 33 patterns already presented in the X-ray powder data file. 62 p. *Government Printing Office, Washington 25, D. C., $0.40.*

Statistical Design of Laboratory Experiments. This volume contains a series of lectures on the philosophy and practical use of statistics in research presented during a colloquim conducted at the Naval Ordnance Laboratory in 1954. 102 p. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $2.75.*

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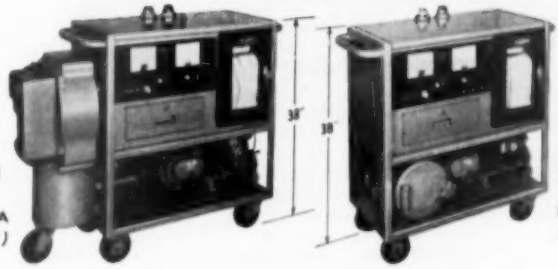

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LETTERS

Pyrophoricity—Plaudit

DEAR SIR:

I should like to take this opportunity to compliment you on the article, "Pyrophoricity—A Technical Mystery under Vigorous Attack." This article has stimulated considerable interest among our management and we would be quite interested in obtaining reprints of this article.

—P. W. HOWE, Superintendent
Health, Safety & Criticality
Nuclear Fuel Division
Olin Mathieson Chemical Corporation
New Haven, Connecticut

Pyrophoricity—Enigma

DEAR SIR:

The article "Pyrophoricity—A Technical Mystery under Vigorous Attack," (NU, Dec. '56, p. 28) provided considerable interesting information both on the mechanism of certain pyrophoric reactions and on particular incidents of metal fires and explosions.

I noted, however, that no reference was made to reactions between metal powders and chlorinated hydrocarbons. There are numerous incidents wherein such spontaneous reactions have transpired, not only with such a relatively unfamiliar metal as uranium, but also with common aluminum powder.

Loosely held chloride radicals of hydrocarbons are capable of reacting with active surfaces and generating heats that will accelerate the reaction. In particular, I refer to the zirconium incident cited on p. 30, which describes a detonation effected when a 2-lb sample of carbon tetrachloride-moistened powdered Zr was heated while under an applied vacuum. The explosion was attributed to a small amount of water, but unless the chloride reaction had been considered, it would be worthy to review the incident, with attention given to chloride analysis of any reaction fragments that might have been gleaned at the site. I say this because in my own experience a spontaneous explosion transpired under an argon atmosphere when a comparable aggregate of uranium powder was moistened with carbon tetrachloride. No externally applied heat was involved.

Should the zirconium experiment be repeated without consideration of the

agency of the carbon tetrachloride, a second explosion may occur.

—JOHN R. BEDELL, Group Leader
Nuclear Division
The Glenn L. Martin Company
Baltimore 3, Maryland

The Author Replies . . .

DEAR SIR:

The zirconium incident referred to was particularly unusual in that the explosion did not occur until after the metal reached an incandescent temperature, a point deleted during editing of the article. The opinion that moisture influenced this specific reaction is based on documented statements of the technician who observed the incident and of the firm who supplied the metal powder involved. It is very probable, as Mr. Bedell suggests, that fragments from this explosion included zirconium chlorides.

Thermodynamic calculations show that highly exothermic reactions between various metals and chlorinated hydrocarbons are theoretically possible, and a number of incidents of this type are known to have occurred. Conditions necessary for initiating such reactions at room temperature are not fully understood. For example, preliminary experiments by an AEC contractor indicated uranium powders could be pyrophorically passivated by treatment with CCl_4! When the identical operation was attempted with a larger batch of the same materials, a spontaneous explosion occurred, seriously injuring the operator.

The preparation of Grignard reagent involves perhaps the most widely used and studied "pure" reaction between metals (normally magnesium) and chlorinated hydrocarbons. The experience in this area leaves no doubt that such reactions can occur in the total absence of water. It should be noted, however, that such reagents react readily with water so that it would not appear unreasonable to suspect that the presence of moisture might materially affect the reaction rate.

In an article entitled "Ursache und Verlauf der Spontanen Zersetzung von Trichlorathylen durch Aluminium" (*Chemie-Ingenieur-Technik*, No. 9–10, 1949), results of research were reported into causative factors for a serious previously experienced aluminum-trichloroethylene incident. The investigators concluded that formation of HCl (one

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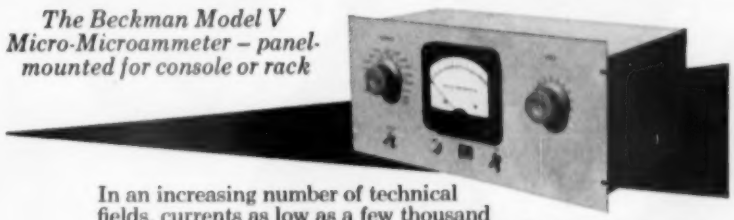

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of several possible trichloroethylene hydrolysis products) was attributed as the initial step of a three-step mechanism that led to the experienced incident.

The AEC study of unusual pyrophoric metal incidents has been largely confined to high-valued metals widely encountered in a radioactive form in the atomic energy field. The emphasis on such metals in the article results solely from the specific area of particular interest to AEC in the pyrophoricity field.

—R. B. SMITH, Fire Protection Engineer
Safety and Fire Protection Branch
U. S. Atomic Energy Commission
Washington, D. C.

Pyrophoricity—A Safe Way

DEAR SIR:

We, here at the Reactor Development Division of Combustion Engineering, Inc., read with a great deal of interest your articles "A Technical Mystery Under Vigorous Attack" and "Lessons Learned from a Pyrophoricity Incident."

We were confronted some time ago with the problems of zirconium scrap storage and/or disposal. Not being able to find an answer by normal means, an all-out effort was made to find a suitable solution to our zirconium proposition.

After a considerable amount of study and experimentation, we believe that we have established a safe method and safe operating procedure for zirconium scrap disposal, which we have used with a considerable degree of success.

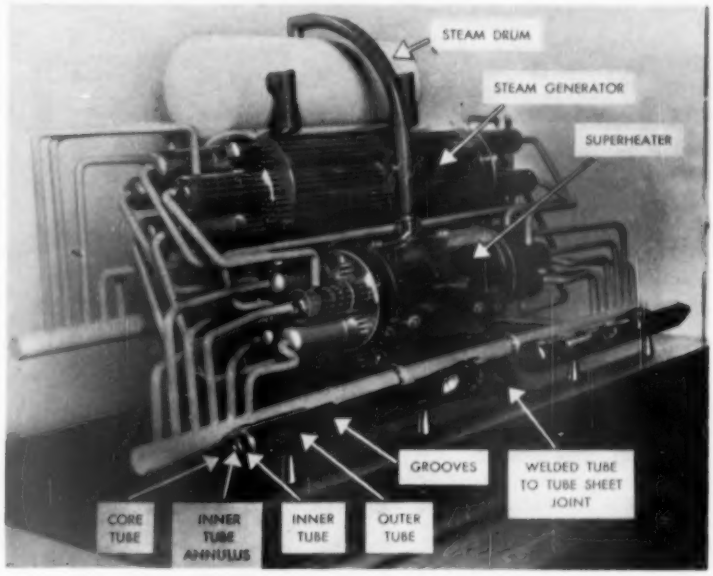
Because zirconium is being used frequently in industry and the dangers inherent in the handling, storage, and disposal of zirconium scrap are not clearly understood, we believe that others might benefit by our experience.

If you agree that an article covering the handling, storage, and disposal of zirconium scrap would be of interest to your readers, we would be very happy to prepare an article for your consideration.

—EDWARD W. KRANS, Safety Engineer
Reactor Development Division
Combustion Engineering, Inc.
Windsor, Connecticut

EDITOR'S NOTE: Mr. Krans informs us that the basis of Combustion's procedure is conversion of the scrap to oxide, which does not present a pyrophoric hazard. We look forward to seeing his manuscript.

PRODUCTS AND MATERIALS



Steam Generator for Liquid-Metal Reactor Systems

Photo above shows scale model of steam generator designed for use with sodium- or NaK-cooled reactors. Liquid metal is separated from H_2O circuit by double pipe wall. Intermediate volume will conduct any escaping liquid to a safe dump space if either side leaks.

Heat transfer is by conduction from inner pipe containing liquid metal to outer volume containing steam and water. Two pipes make close contact except where longitudinal grooves provide intermediate space. Liquid metal makes double travers of its volume, flowing in through the core tube and back through inner-tube annulus. Inner tube itself is dead-ended.

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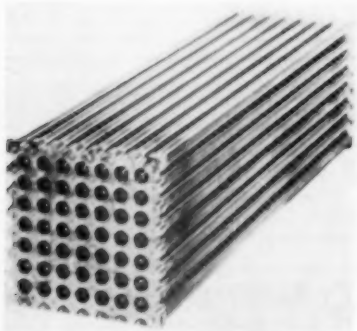
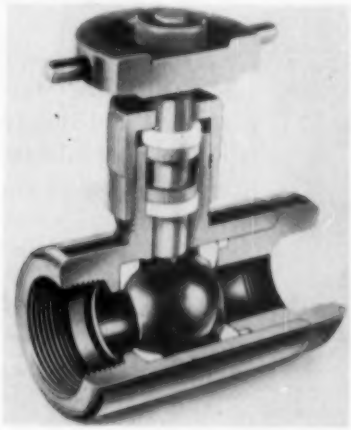


Zirconium-Alloy Tubing

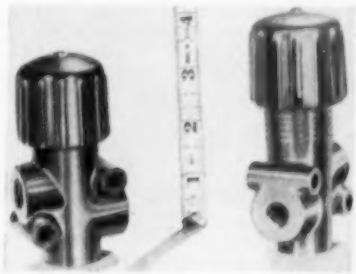
Tubing of Zircaloy-2, an alloy of zirconium with small amounts of iron, chromium, tin, and nickel, has 0.4175-in. od, 0.030-in. wall, both ±0.0015. Originally designed for blanket assemblies of Shippingport reactor.—Superior Tube Co., Norristown, Pa.

Plastic Valves

Two types of polyvinyl chloride valves are offered for handling corrosive fluids.



• PVC valve above uses double-seal ball design. Can be used with plastic or metal piping. Rating is 150 psi at room temperatures, 50 psi at 130° F.—Jamesbury Corp., 62 Millbrook St., Worcester 5, Mass.



• Globe and needle valves are designed for high temperatures and pressures. Operate at pressures to 170 psi and at lower pressures to 170° F.—Chemtrol, 11,008 Santa Fe Ave, Lynwood, Cal.

Corrosion-resistant valves. Relief and back-pressure valves in standard ¼-, ½-, ¾-, and 1-in. sizes are constructed of corrosion-resistant materials, the top works protected by Kel-F thermoplastic diaphragms. Operate at pressures to 1,500 psi and temperatures to 250° F. Pressure setting made with screw driver.—Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

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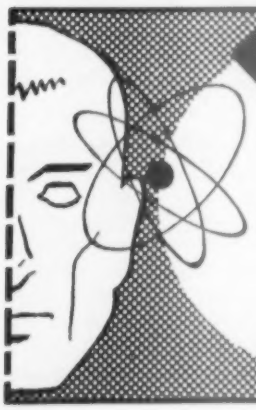

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Photomultiplier Photometer

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LITERATURE AVAILABLE

Polyethylene. Catalog sheet details expanded foam polyethylene recommended for radiation shielding.—American Agile Corp., 5461 Dunham Rd., Maple Heights, O.

Rolling mills. "Rolling Mills for Processing Nuclear Fuel Elements" is title of 12-page booklet.—Stanat Mfg. Co., 500 Shames Dr., Westbury, N. Y.

Electron microscopes. Brochure gives data on construction, operation of electron microscopes.—North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Radiochemicals. Stock compounds in license-exempt 50-μc quantities are given in special listing.—Volk Radiochemical Co., 5412 N. Clark St., Chicago 40, Ill.

Periscopes. Industrial periscopes for various types of remote observations are described and illustrated in 4-page bulletin.—Lenox Instrument Co., 2010 Chancellor St., Philadelphia 3, Pa.

Beta-gage controls. Accuracy strip-thickness control systems for metal-working are described in 12-page bulletin.—Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.

Metal laminates. Sandwiches of various metals for nuclear power, condensers, heat exchangers, etc., are described in 8-page booklet.—Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn.

Metallurgy. Folder describes plant and facilities of metal-forming-equipment producer.—Fenn Mfg. Co., Newington, Conn.

Closed-circuit TV. Illustrated 28-page guidebook shows latest systems for color and black-white TV.—Radio Corp. of America, 30 Rockefeller Plaza, N. Y. 20, N. Y.

Ventilation. Corrosion-proof ventilating and exhaust systems are subject matter of 12-page literature.—American Agile Corp., PO Box 168, Bedford, O.

INDUSTRY NOTES

▶ **William B. Johnson and Associates** 126 Liberty St., N. Y. C., are now representatives in the East of **Volk Radiochemical Co.,** Chicago, Ill.

▶ **Packard Instrument Co.,** La Grange, Ill., are Midwestern sales representatives of **New England Nuclear Corp.,** Boston, Mass.

▶ **Detectolab** is now merged with **BJ Electronics,** a division of Borg-Warner Corp., under the name **Detectolab-B. J. Electronics,** 3300 Newport Blvd., Santa Ana, Cal.

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NEWSMAKERS

Arthur E. Ruark, physics professor at Alabama Univ., has been chosen by AEC to head Project Sherwood, the controlled fusion project. He succeeds **Amasa S. Bishop,** now AEC's liaison officer in Paris.

Thomas H. Pigford, associate professor of nuclear and chemical engineering at MIT, has joined General Atomic as chairman of the department of reactor engineering at the new Hopkins Laboratory in San Diego. A specialist in the nuclear, mechanical and chemical design of power reactors, he has also done work in isotope separation, purification of reactor materials and reprocessing of fuels. Together with Manson Benedict he originated the graduate nuclear engineering program at MIT. General Atomic also engaged **C. Arthur Rolander,** deputy director of security for AEC, as assistant to division general manager Frederic de Hoffman. He will be in the Washington office of the parent General Dynamics Corp.

Metals & Controls Corp. has set up a separate Nuclear Products division, with vice president **Jerome Ottmar** as general manager, **Sidney Siegel** as engineering manager, **Thomas Snyder** as production manager, and **Arthur R. Matheson** as manager of contract administration.

Frank B. Huke has been appointed sales manager of Norton Co.'s newly-formed electrochemical division, but will continue to serve also as chief atomic products engineer. He has been associated with the atomic energy program since the metallurgical project at Chicago Univ. in the early days of the Manhattan District.

Serge E. Golian is now head of the reactor branch at the Naval Research Laboratory in Washington, D. C.

John W. Turk has been named to the newly-created post of nuclear development engineer by Southwestern Gas & Electric Co., Shreveport, La.

R. L. Carter, materials research group leader at Atomics International (NAA), has been named project engineer for projects primarily concerned with the background technology of sodium graphite reactors. **B. H. Colmery** became project manager for OMRE, succeeding **G. V. Alevizon,** transferred to missile development; **Charles A. Trilling** remains in charge of the OMRE research and development program. AI also named twelve to posts as responsible engineer on as many development projects: **G. O. Haroldsen** on the gas treatment project; **R. H. J. Gercke** on a physical properties and gas solubility project; **H. E. Kline** on a corrosion study project; **C. R. Davidson** on hydraulic tests of coolant; **E. L. Colochman** on development of optimum hydrocarbon coolants; **J. M. Davis** on SRE hot cell windows; **S. H. Fitch** on research reactor safety element development; **W. W. Scott** on dynamics of OMR power plants; **R. A. Atz** on SRE pump development; **E. C. Phillips** on SRE safety rod development; **J. D. Howell** on OMR controls and safety systems, and **Jack Jacobsen** on OMR structure and primary loop studies.

Lee I. Davenport, executive vice president of Perkin-Elmer Corp., Norwalk, Conn., has been named to an executive post with Sylvania, preparatory to becoming president of Sylvania-Corning Nuclear Corp. upon its formation in the near future.

Aerojet-General Nucleonics has engaged **S. Nakazato** and **Robert H. Chesworth,** both formerly with Atomics International, as nuclear engineers—Nakazato to do systems analysis on various reactor concepts, Chesworth to do preliminary design on the Gas Cooled Reactor Experiment.

Sherwood L. Fawcett, specialist in nuclear engineering and heat transfer at Battelle, has been promoted to assistant manager of the physics department.

A. C. Menius Jr. has been appointed head of the physics department at North Carolina State College, and will have responsibility for associated nuclear engineering activities there. He has been acting head since **Clifford Beck** went on leave of absence to AEC.

Paul M. Brister has been named manager of the engineering design section of Babcock & Wilcox's manufacturing and engineering department.

Universal Atomics Corp. has appointed **Alan R. Pearlman** chief engineer.

Clarence Zener has been appointed director of the Westinghouse Research Laboratories, after five years as an associate director and a year as acting director of the 800 man staff.

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L. W. Fromm of Argonne, until recently an EBWR project leader, has been appointed project manager for ARBOR, the big new experimental boiling reactor.

Charles W. Terrell, North Carolina State physicist, has been named supervisor of reactor operations at Armour Research Foundation.

Frank W. Hurd is the new director of research at Union Carbide Nuclear Co. He has been with Carbide's atomic activity since 1943.

AEC's Oak Ridge Operations Office has set up an inspection division, with **Leo Dubinski,** formerly deputy director of the organization and personnel division, as director, and **H. J. McAlduff, Jr.,** formerly of the research and development division, as deputy director. **Willis Hay,** assistant chief of the administrative branch at the Portsmouth, Ohio, area, succeeds Dubinski as deputy director in organization and personnel.

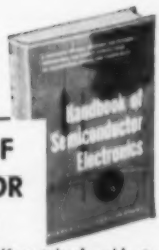
Davis R. Dewey II has resigned as vice-president of High Voltage Engineering. No successor has yet been named.

John D. Trimmer has been placed in charge of nuclear systems development in the new systems division of Bendix Aviation Corp. He had been physics professor at Tennessee Univ. and a consultant on reactor control at Oak Ridge.

Paul C. Fine, an AEC staff member since 1947 and most recently assistant to Commissioner John von Neumann, has been appointed director of the Office of Operations Analysis and Planning in the General Manager's Office.

Victoreen Instrument Co. has elected **Raymond F. Shima** as executive vice-president and general manager, in addition to his former duties as treasurer. He becomes the firm's chief executive officer, succeeding resigned president **Cyrus W. Haller.** The presidency will be left open until the annual meeting. **Richard T. Brown,** company secretary, was elected vice president.

Richard A. Fayram, 36, senior research engineer at Aerojet-General Nucleonics, died Dec. 25, 1956, after a sudden brief illness. Associated with the atomic energy field since 1947, he specialized in marine applications of nuclear power. He had taught at California U., Berkeley, and received a Fulbright scholarship in 1955 to study nuclear ship propulsion in Oslo, Norway.



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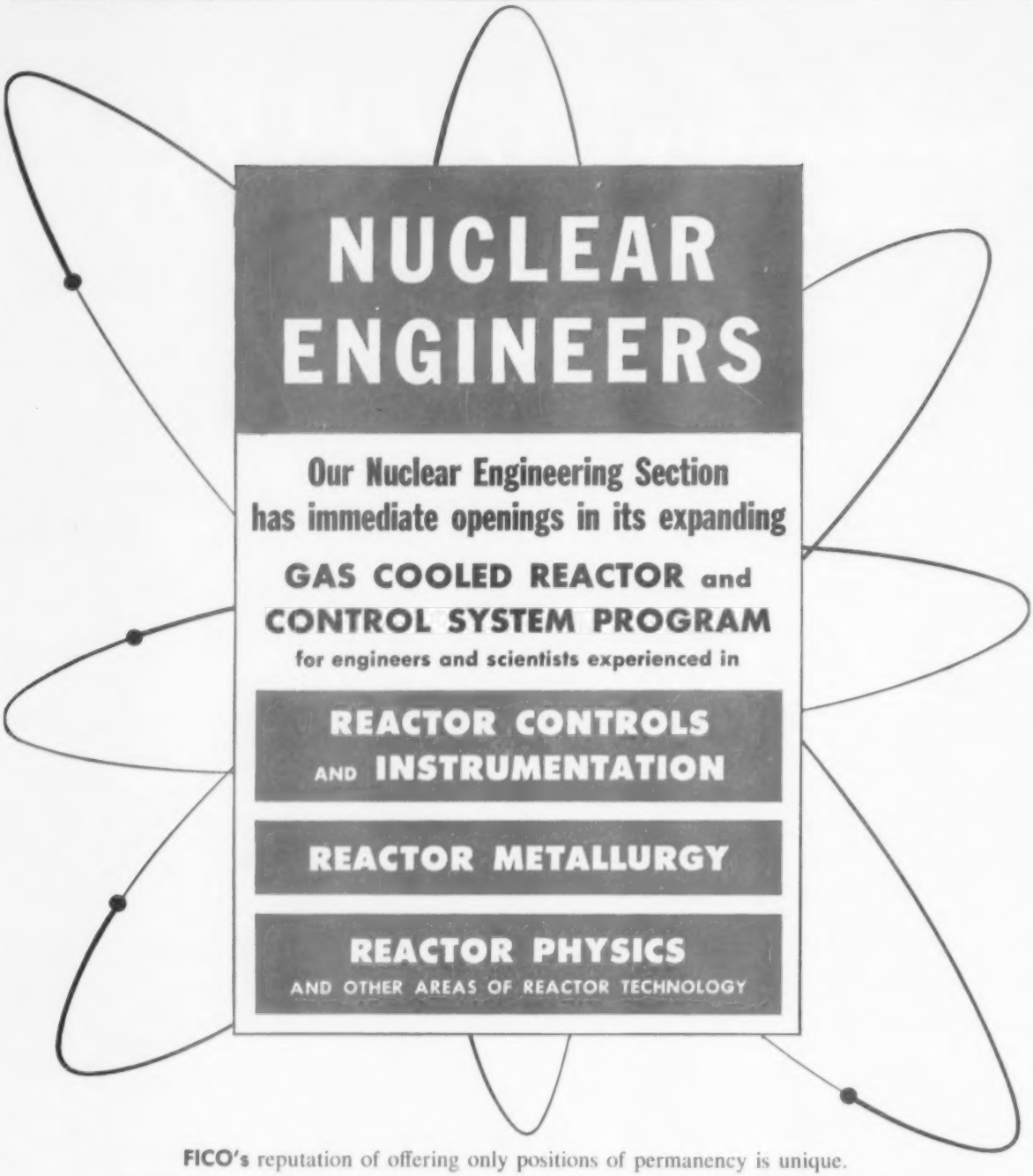

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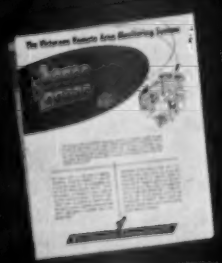

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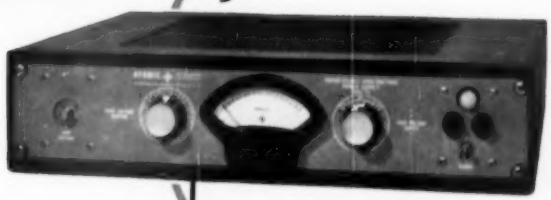

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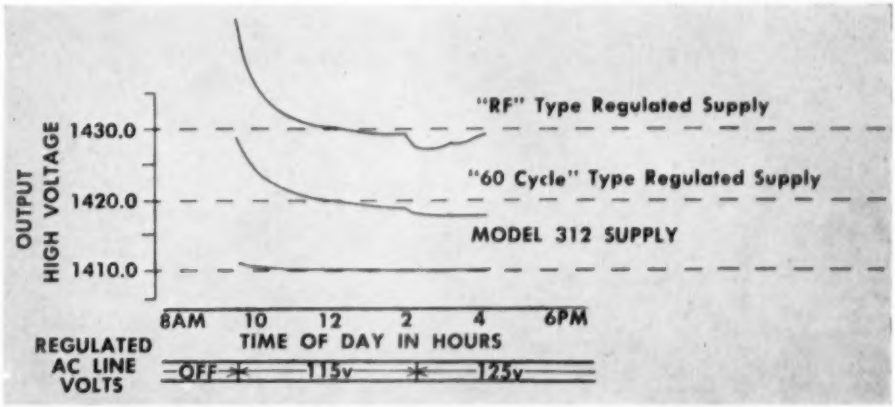

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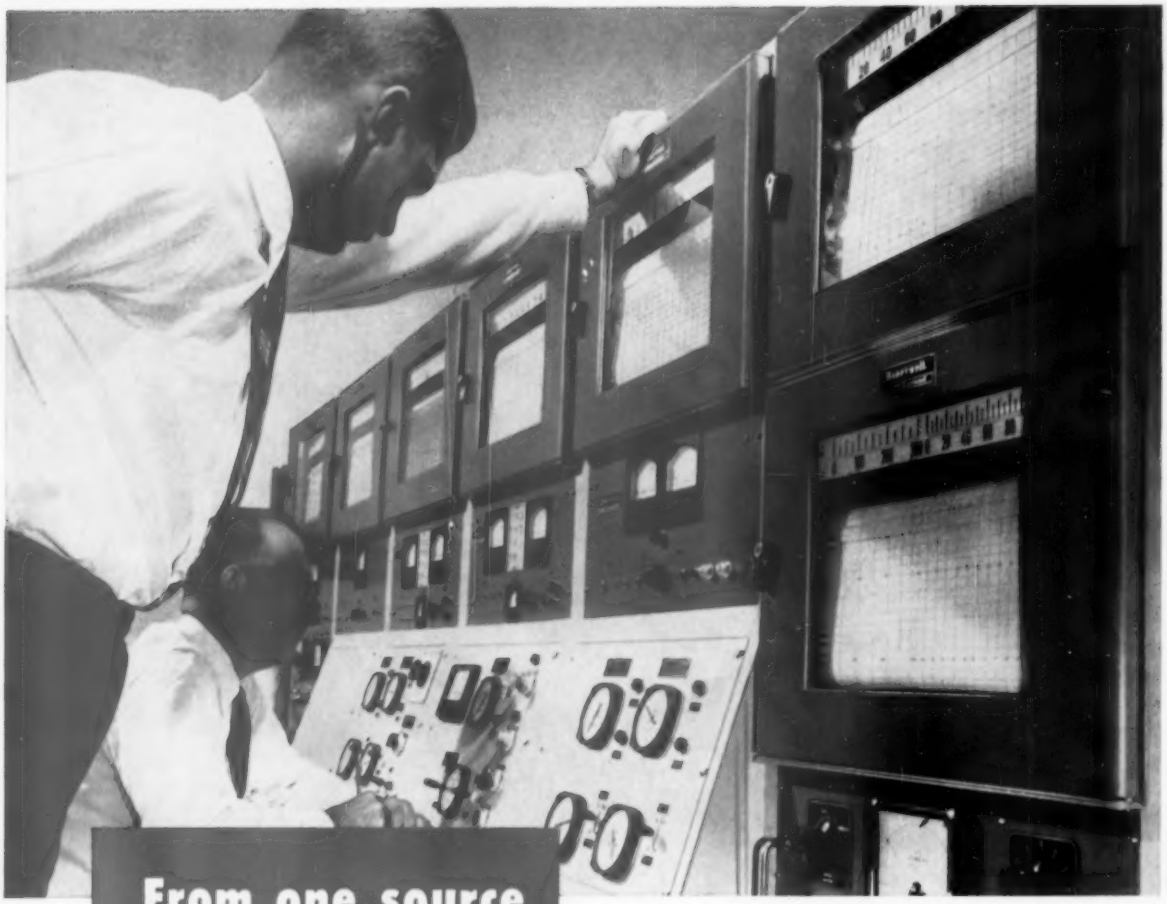

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